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SCIENCE PRIMER

MAGNETISM  
AND  
ELECTRICITY

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REV. JAMES OVEREND









ELEMENTARY EXPERIMENTS

IN

MAGNETISM & ELECTRICITY

*INTENDED FOR THE USE OF JUNIOR PUPILS ·*  
*IN SCIENCE CLASSES*

BY

THE REV. JAMES OVEREND, M.A.

*SECOND EDITION*

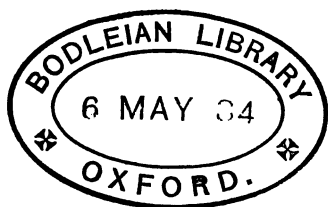
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## PREFACE.

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**I**N writing this small Elementary Text-Book, the Author has followed the lines laid down in a "List of Experiments in Physics," written by Dr. Guthrie, and published some twelve months ago by the Science and Art Department of the Committee of Council on Education. The Author's primary object has been to supply the Junior Pupils of his own classes with a book suited to their age and attainments; but it is, at the same time, his hope that it may also prove useful in the hands of others commencing the study of Magnetism and Electricity. For some valuable hints as to the classification of examination questions given at the end of the book, the Author is indebted to the Rev. D. Balsillie, M.A., House Governor of Donaldson's Hospital, Edinburgh.

*January 1879.*



# MAGNETISM.

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**Definition of term.** By the term Magnetism is understood that property possessed by iron, steel, and some other bodies, by virtue of which other pieces of iron and steel are attracted to them.

**Derivation of word.** Magnetism is derived from the name Magnesia, a town in Lydia, where natural magnets were stated by ancient writers to abound.

**The Natural Magnet, or Loadstone,** is an ore of iron every molecule or smallest particle of which is composed of three atoms of iron combined with four atoms of oxygen gas. Its chemical name is Triferrie Tetroxide, and its chemical formula  $\text{Fe}_3\text{O}_4$ , *ferrum* being the Latin name for iron. This loadstone or natural magnet has the power of attracting small pieces of iron, and if balanced and suspended will point nearly north and south, like an artificial magnet. It has also the power of conferring magnetism upon pieces of steel if rubbed along one of its ends a few times.

**Artificial Magnets** are pieces of iron or steel which have been under the action of either the loadstone or other magnets, or of the electric current, or have been subjected to percussion while in certain positions.

**Permanent Magnets** are those magnets which

retain their magnetic properties permanently. They are bars of hard steel, either straight or bent in the form of a horseshoe.

**Temporary Magnets** are those which retain their magnetism only so long as they are under the influence either of other magnets or of the electric current. They are bars of soft iron, either straight or bent.

**Magnetic Polarity** is that property possessed by a magnet, by virtue of which it points towards the earth's poles when freely suspended.

**Poles of a Magnet** are its two points of greatest attraction and repulsion. They are near the two ends.

**Equator of a Magnet**, an imaginary line drawn across a magnet, joining all points where attraction and repulsion are equal. As a rule, this line divides the magnet into two equal parts; or, in other words, it is drawn across the middle of the magnet.

### MAGNETIC POLARITY.

**Experiment 1.** Take off the keeper or armature of a horseshoe magnet; balance it by tying a thread round its middle, and suspend it. It comes to rest nearly north and south. Call the end pointing north the north-seeking pole, and that pointing south the south-seeking pole. Take a strip of steel which has been rendered magnetic by discharging a Leyden battery across it, and suspend it in the same manner. It will also come to rest nearly north and south.

**Experiment 2.** To show that unlike poles attract and like poles repel one another.

Holding the magnetized strip by its thread, bring its north-seeking end to the north-seeking end of the armature; it will be repelled. Again, bring the south-seeking end of the strip to the north-seeking end of the keeper; attraction will now take place.

**Experiment 3.** Suspend two magnetized strips of steel with like poles adjacent, that is, N. pole to N. pole and S. pole to S. pole. The strips will repel one another. Now suspend them with unlike poles adjacent, and they will now attract each other.

**Experiment 4.** To show that the poles are near the two ends. Scatter iron filings over a magnet, and they will cluster most abundantly around the two ends, showing that the points of greatest attraction are there.

**Experiment 5.** To find out which is the north and which the south pole of a magnet. Bring one end of the magnet to be tested near the N. pole of a suspended magnetic needle. If it be attracted, that end is a S. and the other a N. pole; if it be repelled, the repelling end is a N. and the other a S. pole.

### DISTRIBUTION OF MAGNETISM IN A MAGNET.

**Experiment 6.** To magnetize a strip of steel. Draw it from end to end several times over one of the poles—say the N. pole—of a strong permanent magnet. The strip will be magnetized, the end which last leaves the N. pole of the magnet becoming a S. pole.

**Experiment 7.** To show that the smallest

particle of a magnet is itself a magnet. Break a magnetized strip of steel into two halves, and present in succession the two ends of each half to the N. pole of a suspended magnetic needle. One end of each half will attract and the other end will repel the N. pole of the suspended magnet, showing that each half is a perfect magnet. Break the halves into quarters, and try each in the same manner as before, and each quarter will prove to be a perfect magnet. Again break into eighths, sixteenths, and so on; and each part will be found to be a perfect magnet. Hence we infer that the smallest part of every magnet is itself a perfect magnet, with a N. and S. pole. We may likewise infer from this experiment that we cannot obtain a magnet with a single pole.

**Experiment 8.** Place the head of a large nail in contact with the N. pole of a horseshoe magnet. Bring the N. pole of a suspended magnetic needle near the point of the nail and it will be repelled, showing that the point is a N. pole.

### COERCIVE FORCE.

**Definition.** Coercive force is that force in iron and steel which resists magnetization and demagnetization.

In soft iron this force is very small. Hence soft iron may be easily and strongly magnetized, but soon loses its magnetism; whereas hard steel is magnetized with difficulty, but retains its magnetism permanently. In the language of the theory of magnetic fluids, coercive force is the force which resists the decomposition and the recomposition of the magnetic fluids.

**Experiment 9.** Place one end of a soft iron nail in contact with one of the poles of a horseshoe magnet. The nail at once becomes a strong magnet by induction, and adheres firmly. Now try a strip of hard steel. To render this strongly magnetic it will be necessary to draw it several times, from end to end, over one of the poles of the horseshoe magnet. The reason of this difference is that coercive force in the soft iron nail is small, while it is great in the hard steel.

**Experiment 10.** Suspend a steel ball by means of a cord, and also a soft iron ball of the same size. Bring near the steel ball the N. pole of a magnet; the ball moves a little, but is not drawn to the magnet. Now bring the same pole to an equal distance from the soft iron ball, and it will be at once attracted. The reason of this difference is that coercive force being great in the steel, the magnet can only induce a weak S. pole on the near side and a weak N. pole on the far side; while in the case of the soft iron, the coercive force being very small, the ball becomes a strong magnet; then, as attraction and repulsion are mutual actions, the steel is only slightly moved, while the soft iron is strongly attracted.

**NOTE.** Why a piece of soft iron is attracted by a pole of a magnet. Suppose the N. pole of a magnet to be brought near one end of a small bar of soft iron, the latter will be attracted, because the N. pole acts *by induction* upon it, causing the near end to become a S. and the far end a N. pole; the soft iron is therefore being both attracted and repelled by the N. pole of the permanent magnet; but because attraction acts at

a less distance than repulsion, the soft iron is attracted, and that with a force equal to the difference between the force of attraction and the force of repulsion.\*

**Theory of magnetic fluids.** This theory supposes that there resides in each atom of iron and steel a compound fluid capable of being resolved into N. and S. fluid. When a bar of iron is under the influence of a magnet or a current of electricity these two fluids separate, the N. fluid in each atom looking in one direction, and the S. fluid in the opposite direction, and the bar is magnetized. The fluid does not pass from one atom to another as the electric fluid is supposed to do. If the bar be of soft iron, and if it be now removed from the influence which caused the two fluids to separate, the attraction they possess for each other causes them to recombine in each atom, and the bar loses its magnetism, or, in other words, returns to its neutral state. It has to be remembered that the existence of magnetic fluids is quite theoretical.

## INDUCTION.

**NOTE.** Magnetic induction is the action of a magnet upon a piece of iron or steel when near to or in contact with it.

The iron or steel becomes magnetic by the influence of the presence of the magnet, unlike poles being always adjacent to (side by side) each other in the inducing and induced magnets.

\* It must be noted that at the same time the soft iron bar is also exerting attraction and repulsion upon the magnet.

**Experiment 11.** Hang a number of soft iron nails of the same length from, say, the N. pole of a horseshoe magnet. The free ends will repel one another. The reason of this is that the N. pole of the magnet acts by induction upon the nails, causing their near ends to be S. and their far ends N. poles. Then, in obedience to the law that like poles repel one another, the nails behave as they do. The near ends do not repel one another, because they are held fast by the N. pole of the magnet.

**Experiment 12.** Fix a horseshoe magnet upright, standing on its bend. Suspend a large iron nail by a thread in such a manner that its head will be half an inch above its N. pole, and its point the same distance above its S. pole. Now bring the N. pole of a second magnet near the point of the nail. It will be repelled, for the horseshoe magnet acting by *induction* caused the head of the nail to be a S. pole and the point a N. pole; and hence, because N. repels N., the point of the nail is repelled.

**Experiment 13.** To reverse polarity. Bring the N. pole of a very strong magnet to the N. pole of a small magnetic needle lying on a table. The N. pole of the needle will be attracted, in apparent contradiction of the law that like poles repel one another. The N. pole of the magnet, being very powerful, acts by *induction* with such force as first to demagnetize the needle and afterwards to magnetize it with reversed poles. The N. pole of the strong magnet does not therefore really attract the N. but the S. pole of the small needle.

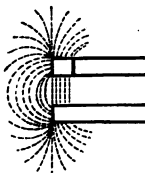
**RELATION OF HEAT TO MAGNETISM.**

**Experiment 14.** Heat red-hot an iron ball and suspend it by an iron hook. Bring a pole of a powerful magnet near to the ball, and the latter will not be attracted. Keeping the magnet in the same position, wait until the ball has cooled, and when sufficiently reduced in temperature it will be attracted. This shows that iron cannot be magnetized when red-hot.

**Experiment 15.** Heat a bar magnet red-hot, and after it has cooled again bring each end in succession to the N. pole of a suspended magnetic needle. Attraction will take place in both cases, showing that the bar has lost its magnetism; for otherwise we should have attraction with one end and repulsion with the other. The heat has destroyed its magnetism. It may, however, be again magnetized in the usual way.

**MAGNETIC CURVES.**

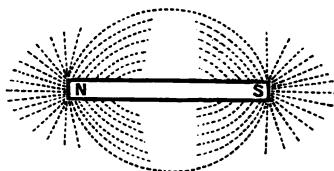
**Experiment 16.** Place a sheet of cardboard over a horseshoe magnet lying on a table. Scatter iron filings all over the cardboard, and tap the latter. Notice the curves round the two poles, and draw them (see annexed figure).



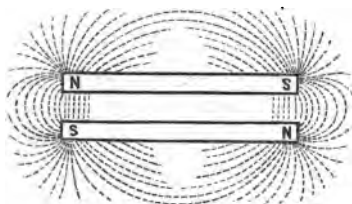
Iron filings around the two ends of a horseshoe magnet.

**Experiment 17.** Do the same with a bar magnet, with two bar magnets with unlike poles side by side, and again with their like poles side by side. Notice the curves in these three cases, and

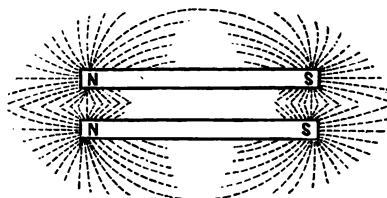
make drawings, which will be similar to those given below.



Iron filings around bar magnet.



Iron filings around two bar magnets with *unlike* poles adjacent.



Iron filings around two bar magnets with *like* poles adjacent.

## THE EARTH'S MAGNETISM.

**Experiment 18.** Suspend an unmagnetized knitting-needle by a thread, so that it hangs horizontally. Now magnetize it by drawing it from end to end several

times over one of the poles of a magnet. Allow it to come to rest, and it will be found to be no longer horizontal, but will incline or dip, with its N-seeking pole pointing downwards towards the north. This is said to be owing to the earth's magnetism acting upon the suspended needle, and causing it to point towards its magnetic poles.

**Experiment 19.** Hold a soft iron poker in the same direction as that taken up by the needle in the last experiment. Take a small suspended magnetic needle and bring it near that end of the poker which points downwards. The N. pole of the needle will be repelled, and its S. pole attracted, showing that that end of the poker is a N. pole. Pass the needle upwards close to the poker, and its S. pole will continue to be attracted until the middle is reached, after passing which the needle will turn round, and its N. pole will be attracted; and so onwards to the upper end of the poker, which we say has been magnetized by the inductive action of the earth.

**Experiment 20.** Effect of percussion. While in the position mentioned in the last experiment, strike the end of the poker several times with a hammer. This percussion will be found to have conferred *coercive force* upon the poker, which now retains its magnetism in any position.

**Experiment 21.** The earth's magnetic force directive and not translative. Float a small magnetic needle, fixed horizontally to a cork, on water. The needle will point nearly N. and S. ( $19^{\circ}$  W.), but will not float towards the north. This is owing to the great distance of the earth's magnetic pole, which is both

attracting and repelling the needle, the difference between attraction and repulsion being so small that it gives direction (or a motion of rotation) only to the needle, and not a motion of translation.

**Experiment 22.** Hold a soft iron poker in the magnetic meridian (nearly N. and S.) and in the line of dip, its point downwards and knob upwards. While in this position test it with a magnetic needle, and its point will be found to be a N. pole and its knob a S. pole. Now hold the poker horizontally E. and W., and again test. It will now be found that either end will attract the N. pole, which shows that it is no longer magnetic, as it was in its former position.

**NOTE.** The earth a magnet. We say the earth is a magnet because it acts just like one upon suspended magnets and upon soft iron when in certain positions. Upon the horizontal needle it exerts a force which causes it to point towards the N. and S. ; and it causes the vertically-suspended needle to dip. It also induces magnetism in soft iron, when held in the magnetic meridian and in the line of dip. The earth, then, acting like a magnet, has two poles, one in the northern hemisphere, to the north of Hudson's Bay (lat.  $70^{\circ}$  N. and  $96^{\circ} 43'$  W. long.), and another in the southern hemisphere ( $75^{\circ} 30'$  S. lat. and about  $154^{\circ}$  E. long.).

The earth's magnetic equator may be defined as an imaginary line connecting all points on the earth's surface where the dipping needle is horizontal. This does not coincide with the geographical equator any more than the magnetic poles of the earth agree with the geographical poles.

The earth's magnetic poles are those two points on the earth's surface where the dipping needle is vertical.

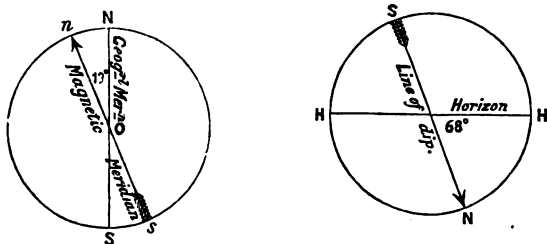
A magnetic meridian is an imaginary line drawn round the earth, and passing through its two magnetic poles.

A geographical meridian is an imaginary line drawn round the earth, and passing through the two geographical poles.

Declination is the angle which the horizontal needle (compass needle) makes with the geographical meridian.

Inclination is the angle which the dipping needle makes with the horizon.

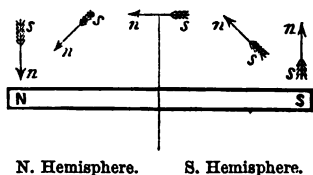
The direction in which the compass needle points in London. About  $19^{\circ}$  W. of the geographical meridian. It is, however, subject to variations.



The direction of the dipping needle in London. It makes an angle of about  $68^{\circ}$  with the horizon. This angle is also subject to variation.

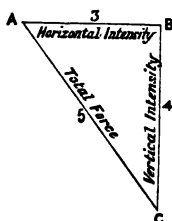
How the dipping needle would behave if conveyed from the earth's magnetic pole in the northern hemisphere to that in the south-

ern hemisphere. At the pole in the N. hemisphere the needle is vertical, its N.-seeking pole pointing downwards. When conveyed southwards it dips less and less till it arrives at the earth's magnetic equator, when it is horizontal. South of this imaginary line the S.-seeking pole begins to dip downwards, and does so more and more until the earth's other magnetic pole is reached, when the needle will be again vertical, but this time with its S.-seeking pole pointing downwards.



The earth's magnetic intensity is resolved into (1) horizontal intensity, by which is meant that portion of the earth's magnetism which acts upon the horizontal magnetic needle, causing it to set in the magnetic meridian, and (2) vertical intensity, which acts upon the vertical or dipping needle, causing it to dip.

The resultant of these two forces is called the earth's total force. Thus, let  $AB$  = horizontal intensity and  $BC$  = vertical intensity of the earth's magnetism. Then  $ABC$  being a right angle,  $AC$  will represent the total force.



Let  $AB = 3$ , and  $BC = 4$  ;

Then  $AC$  (total force)

$$\begin{aligned}
 &= \sqrt{AB^2 + BC^2} \\
 &= \sqrt{3^2 + 4^2} \\
 &= \sqrt{25} \\
 &= 5
 \end{aligned}$$

The mariner's compass consists of a magnetic needle attached to a card marked with the cardinal points (N., S., E., W., etc.), and balanced so that it always rests in the magnetic meridian, no matter in what direction the ship in which it is placed may turn. It is enclosed in a strong brass case called a "binnacle." From the fact of the needle always pointing in the same direction, the mariner is enabled by its assistance to steer his ship in the direction he wishes it to take.

## FRictionAL ELECTRICITy.

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**Other names.** "Static" electricity, because it resides on the surfaces of bodies. "Franklinic" electricity, in honour of Professor Franklin. "High Tension" electricity, in opposition to current electricity, which is of low tension—tension meaning tendency to escape.

Experiments in frictional electricity are most successful when the atmosphere is dry—moisture, as a conductor, allowing the electricity to dissipate itself. All the apparatus should be dry and hot, and should be screened from draughts which carry moisture.

**Def. Friction.** The act of rubbing.

## ATTRACTION AND REPULSION.

**Def. Attraction** is the act of drawing to.

„ **Repulsion** is the act of driving away.

**Experiment 1. Attraction.** Balance a long wooden lath on the rounded bottom of a flask standing on its neck; and spread on a table a little sawdust, a few feathers, bits of paper, gold-leaf, pith balls, and other light bodies. Now take the following substances, and

without rubbing, bring them near to the lath and other light bodies—resin, amber, sticks of sulphur, shellac, sealing-wax, indiarubber tube, etc. There will be no motion of the light bodies. Now, after making these substances dry and hot, and rubbing them with hot dry flannel, bring them in succession near to the light bodies. This time they will all be attracted, showing that rubbing has altered the condition of the resin, etc. Now do the same with a smooth glass tube or rod (which must be rubbed with amalgamated \* silk), brown paper brushed with clothes-brush, thin notepaper rubbed with indiarubber, film of collodion drawn through the dry fingers, and silk ribbon drawn through the fingers armed with indiarubber tubing. The light bodies will again be attracted, and the thin notepaper and silk ribbon will cling to the wall. Rubbing (friction) has altered the condition of these bodies—in other words, it has caused them to be electrified.

**NOTE.** The words electricity, electrified, etc., are derived from the Greek word *elektron*, amber. Amber is a fossil resin, yellowish in colour, sometimes transparent, and is used for the manufacture of ornaments of various kinds. It was the substance first noticed (by Thales) to have the property of attracting light bodies when rubbed.

**Experiment 2. Repulsion.** Suspend in loops a light stick of sealing-wax which has been rubbed with flannel. Bring near to it another stick of sealing-wax similarly rubbed. The suspended stick will be repelled.

\* That is, silk spread with a mixture of mercury, tin, and zinc.

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Now suspend a rod of glass which has been rubbed with silk, and bring near to it another glass rod also rubbed with silk. Repulsion will again take place. Hence we say that similar bodies similarly rubbed repel each other; or, in other words, bodies similarly electrified repel each other.

**Experiment 3. Attraction.** Hold the hand near to the suspended sealing-wax and glass in succession. They will both move towards the hand.

**Experiment 4. Attraction.** Rub sealing-wax and shellac with flannel, and suspend them in separate sets of loops. A glass rod which has been rubbed with silk will attract both.

**Experiment 5.** To prove that there are two kinds of electricity. Suspend sticks of sealing-wax, sulphur, shellac, indiarubber, etc. (resinous bodies), after rubbing them with flannel, and bring near to them any resinous body which has also been rubbed with flannel, and they will all be repelled. Now bring near to them a glass rod rubbed with silk. This time they will all be attracted, showing that there is a difference between the condition of sealing-wax, etc. (resinous bodies), rubbed with flannel and glass (a vitreous body) rubbed with silk. In other words, the electricity developed on resin is different from that developed on glass when rubbed with flannel and silk respectively. The electricity on the glass is called positive (+ E), and that on the sealing-wax negative (- E).

**Experiment 6.** Now suspend a thin smooth glass tube rubbed with silk, and bring near to it a glass rod, also rubbed with silk. Repulsion will take place. Now

try the suspended tube with sealing-wax rubbed with flannel; the tube will be attracted.

From experiments 5 and 6 we prove that there are two kinds of electricity, and that like electricities repel, and unlike electricities attract, each other.

That is, + E repels + E.

- E „ - E.

+ E attracts - E.

- E „ + E.

**Experiment 7.** Place a sheet of thin notepaper on a hot mahogany board, and rub it briskly with bottle caoutchouc. Cut it into strips with sharp knife, and hang the strips from a thread fastened to a bent pin. The strips will all repel each other (being similarly electrified). Now bring excited glass rod near to strips; they will all be repelled. Now try sealing-wax rubbed with flannel; this time they are all attracted. We infer from this that the strips are electrified with + E. We may also infer, as in experiments 5 and 6, that there are two kinds of electricity.

**Experiment 8.** Touch the cap of a gold-leaf electroscope with excited sealing-wax; the leaves diverge, being similarly electrified by contact. Now touch the cap with excited sulphur; the leaves diverge still further, because they receive a further charge of the same kind of electricity as before. Now touch the cap of the instrument with rubbed glass; the leaves will this time diverge less, because they receive a charge of a different kind of electricity, which tends to neutralize that received from the sealing-wax and sulphur.

**Experiment 9.** Rub hot glass rod with fur; the

rod will be electrified with - E. Now rub sealing-wax with gun-cotton; the wax will be excited with + E.

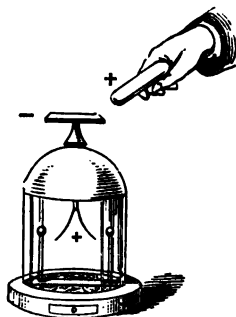
**NOTE.** + E was formerly called vitreous electricity because it was developed on glass.

- E was called resinous electricity because developed on resinous bodies.

This division has been abandoned, because - E can be produced on glass and + E on resin, as shown by the last experiment.

### CONDUCTION AND ISOLATION.

**NOTE.** The electroscope is an instrument for testing the presence of electricity, the kind of electricity with which a body is charged, and the conductivity of bodies. It consists of a metal rod enclosed in a tube of glass, and having a cap or knob at its upper end and two strips of gold-leaf hanging from its lower extremity; the whole being supported by a glass jar, which encloses and isolates the gold-leaves, and preserves them from draughts of air, which might cause them to move at an inconvenient time.



The Electroscope.

**Experiment 10.** Fasten one end of a long copper wire to the cap of an electroscope, and loop the other end round a smooth glass rod. Now rub the glass with a piece of amalgamated silk, and allow the loop to slip up and down the rod. The gold-leaves will diverge, because

the electricity on the rod flows along the wire to the gold-leaves, which thus become charged with the + E from the rod; and, being similarly charged, they repel each other. Now do the same with common twine and with cotton thread; again the leaves diverge. Try a silk thread; this time the leaves will not move. Wet the silk and try again; the leaves at once diverge. These experiments prove that copper wire, twine, cotton thread, and wet silk are conductors, and that dry silk is a non-conductor or isolator (sometimes called insulator).

Def. A conductor is a body which will allow electricity to flow along it.

Def. An isolator is a body which will not allow electricity to flow along it.

Def. Conduction is the act or property of conducting E.

Def. Isolation or insulation is the non-conducting property of a body.

Experiment 11. Hold in the hand a metal candlestick or an iron poker, and strike it with flannel. Bring it to the cap of an electroscope; the gold-leaves will not move. Now hold the candlestick or poker in a sheet of vulcanized caoutchouc (indiarubber); again strike it with flannel, and bring it to the electroscope; this time the leaves will diverge. In the first case, the electricity developed escaped along the metal and through the body to the ground, both being conductors. In the second case, the metal being isolated by the indiarubber, the electricity could not escape, and so made the gold-leaves diverge.

**NOTE 1.** The ground is the great reservoir of electricity, to which it always escapes, when free to do so.

**NOTE 2.** All bodies were formerly divided into **electrics** and **non-electrics**. Bodies which could be electrified while held in the bare hand, such as glass, resin, sulphur, etc., being called **electrics**, while the metals and other conductors which could not be so electrified were called **non-electrics**. This division was an unsound one; for conductors can be electrified if properly isolated, as shown by the last experiment. All bodies are therefore **electrics**—that is, all bodies can be electrified by friction.

**Experiment 12.** Make an isolating stool by placing a dry mahogany board on four varnished glass tumblers. Stand on isolating stool, and place a finger on the cap of an electroscope. Let the coat be struck with fur skin by another person. The gold-leaves will diverge, because the body and the electroscope, both being isolated, become electrified with - E by the friction produced by the coat and fur.

**Experiment 13.** Make proof planes by pasting tin-foil on circular bits of cardboard, and fitting them with shellac handles. Now test the bodies mentioned in experiment 1 to see whether they be electrified. For instance, holding a proof plane by its isolating handle, touch with its disc the sealing-wax, and then place the proof plane on the cap of the electroscope. If the leaves separate, the wax is electrified; but if they do not, there is no electricity on its surface. Try the other bodies in the same manner. Thus we may discover whether bodies are electrified or not.

**Experiment 14.** To test the *kind* of  $E$ . Touch cap of electroscope with glass rod which has been rubbed with silk; the leaves will receive a charge of  $+ E$  by contact, and will diverge. While the leaves remain apart, touch some body which has been rubbed, and the kind of electricity of which you wish to test with proof plane, and with it touch the cap of the electroscope. If the leaves diverge more, the body is electrified with  $+ E$ ; and if they collapse, with  $- E$ .

**Experiment 15.** Cause leaves of electroscope to diverge with  $+ E$  as before. Now bring neutral proof plane upon the cap of the instrument. Leaves will diverge less, because the  $+ E$  is now spread over a larger surface, and consequently the leaves become less highly charged. The same thing will occur (and from the same cause) if the leaves be made to diverge with  $- E$  instead of with  $+ E$ .

**Experiment 16.** Suppose the leaves of the electroscope to diverge with  $+ E$ . Place a proof plane or other body charged with  $- E$  on the cap of the electroscope. The leaves will either collapse partially or wholly, and then diverge again, according to the strength of the charge of  $- E$ . These results are due to the same cause as that mentioned in the last experiment.

## INDUCTION.

Induction is the action of an electrified body upon a conductor when brought near to it. The electrified body separates the two electricities, attracting that of opposite and repelling that of same name. For example, a glass rod excited with  $+ E$ , and brought near to an isolated

metal ball, will by its mere presence induce the two electricities to separate, and will attract  $-E$  to the near side, and repel  $+E$  to the far side.

**NOTE.** Theory of electric fluids. This theory supposes that there resides on all bodies a subtle fluid that is capable of being resolved into two fluids, positive and negative. When bodies are unelectrified or neutral, they are supposed to contain these fluids mixed together in equal proportions. When there is an excess of positive fluid on a body, that body is said to be positively electrified; and when the  $-E$  is in excess, the body is negatively electrified. Whenever a certain amount of positive fluid is separated, there is always an exactly equal amount of negative set free. These fluids are liberated from each other in three ways:—

1. By friction.
2. By chemical action.
3. By induction.

It has to be borne in mind that the idea of two fluids is an image merely and not a proved fact. It is convenient and useful, inasmuch as it enables us to account for all the phenomena in the science of electricity.

**Experiment 17.** Bring sealing-wax excited with  $-E$  near to the electroscope; the gold-leaves will diverge because the  $-E$  on the sealing-wax acts by induction upon the instrument, separating the two fluids, attracting induced  $+E$  to the cap and repelling the induced  $-E$  to the leaves, which, being similarly electrified, repel each other. Now remove the sealing-wax, and the leaves will collapse; because, being no longer kept separate by the  $-E$  on the wax, the  $+E$

and - E mingle together and the electroscope returns to its neutral state.

**Experiment 18.** Connect an isolated metal ball with cap of electroscope by means of copper wire. Excite glass rod with amalgamated silk and bring it near the ball. With an isolator now remove the wire from the electroscope, the leaves of which are diverging. Now bring the glass rod near cap of electroscope; the leaves will diverge more, showing that they were previously diverging with + E. The reason of their diverging more is this: When the glass rod was brought near the ball the + E acted by induction upon it, separating the two fluids, attracting - E to the near side of the ball, and repelling induced + E along the wire to the gold-leaves; which becoming positively electrified, repelled each other. On removing the wire with the isolator, and then bringing the glass rod excited with + E to the cap of the electroscope, the + E on the glass rod acted by induction upon it, separating the two fluids, attracting - E to the cap and repelling + E to the gold-leaves, which thus got an extra charge of + E and diverged further.

**Experiment 19.** To test kind of electricity by induction. Make the leaves of an electroscope diverge with - E, by touching cap with excited sealing-wax. Now bring body to be tested near the electroscope. If the leaves diverge more, the body is charged with - E, and if they diverge less, with + E.

**Experiment 20.** Place the hand on the electroscope. Now bring near the cap a body positively electrified. The leaves do not move. Remove first the hand and then the electrified body, and the leaves will

diverge with  $-E$ . The leaves did not diverge at first, because the induced  $+E$  was repelled through the body (a conductor) to the ground, while the induced  $-E$  was held fast in the cap by the attraction of the electrified body. On removing the hand, and afterwards the electrified body, the  $-E$ , previously held fast in the cap, distributed itself over the electroscope, electrified the leaves with  $-E$ , and thus caused them to repel one another.

**NOTE 1. Why light bodies are attracted.**

**Case 1.** If a glass rod positively excited be brought near to a pith ball suspended by a cotton thread, or otherwise in electrical connection with the ground, the  $+E$  will act by induction upon the ball, attracting  $-E$  to its near side, and repelling  $+E$  to the earth. Then, in accordance with the law that unlike electricities attract each other, the pith ball will be attracted.

**Case 2.** If the pith ball be suspended by a silk thread however, or placed upon an isolator—a piece of indiarubber, for instance—the action will be different. In this case the  $+E$  on the glass acts by induction as before, attracting  $-E$  to the near side, and repelling induced  $+E$ , not to the ground, to which it cannot now escape, but to the far side of the pith ball, which is thus being both attracted and repelled at the same time. But because the  $-E$  on the ball is nearer to the glass than the induced  $+E$  is, attraction will be stronger than repulsion, and the ball will be attracted with a force equal to the difference between the force of attraction and the force of repulsion.

Hence light bodies unisolated are more strongly attracted than when isolated.

**NOTE 2.** In case 2 the pith ball is often repelled by the glass rod after it has touched the latter. The reason of this is that the induced  $-E$  on its surface becomes neutralized by contact with the positively electrified rod, and may at the same time receive from it a strong charge of  $+E$ , when repulsion must take place.

### LOCAL ANALYSIS.

**Experiment 21.** Join electroscope and isolated metal ball by wire, as in experiment 18. Bring glass rod positively electrified near the ball, and while in this position remove the wire from the ball with an isolator, and then remove the glass. Now holding the ball by its isolating support, bring it near the cap of electroscope charged with  $-E$ ; its leaves will diverge further, showing that the ball is negatively electrified. Repeat the experiment, this time using shellac rubbed with flannel instead of the glass rod, and it will be found that the leaves will this time diverge less, or collapse, proving that the ball is positive.

**Experiment 22.** Place two isolated balls in contact, and hold excited glass near to one. Remove the other and then the glass rod. By testing as in the last experiment we shall find that the near ball is charged with  $-E$  and the far one with  $+E$ . These two charges were induced by the action of the excited glass rod. Then substitute excited shellac for the excited glass, and

repeat the experiment; the near ball is this time positive and the far one negative, as the electroscope will show.

**Experiment 23.** Bring excited glass near one side of an insulated ball. Take proof plane and touch far side, and hold proof plane over positively charged electroscope; the leaves will diverge further, showing that the far side was positive. Now take another proof plane, touch near side of ball, and again hold it over the electroscope; this time the leaves will diverge less, showing that the near side was negative. Now touch the ball anywhere with the hand, and then remove the glass. Bring the ball (holding it by its insulator) over the same electroscope; the leaves diverge less, showing that the whole ball is now negative.

**Experiment 24.** Bring excited glass rod near the wall. The  $+E$  on the rod acts by induction upon the wall, attracting and holding fast  $-E$  and repelling induced  $+E$  to the ground. Now touch the wall close to rod with proof plane, and bring the latter over a negatively charged electroscope, the leaves of which will diverge further, proving that the wall was negative.

**Experiment 25.** Place a metal tea-tray on four varnished glass tumblers. Over a jet of unlighted gas place two wires, about a tenth of an inch between their two ends, and let one of them be connected with the ground and the other with the tea-tray. Excite hot brown paper with clothes-brush, and lay it immediately on the tray and the gas will be lit; for the brown paper being excited with  $-E$ , acts by induction on the tray,

attracting + E to the upper surface, and holding it fast, and repelling - E. The latter in its passage to the ground leaps across the small space between the ends of the wire, producing a spark, which ignites the gas. Now turn off the gas and turn it on again without lighting it. Lift the brown paper, and the gas will again be lit, this time on account of the induced + E on the upper side of the tray being set free and escaping to the ground.

NOTE. The tray and brown paper act as an electrophoros.

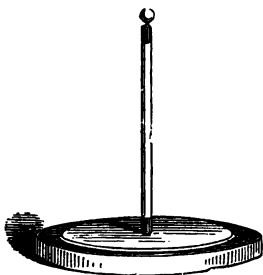
### THE ELECTROPHOROS.

Experiment 26. Repeat the last experiment, but without using the wires. After placing the brown paper on the tray, bring the finger to the under side of the latter, and a spark will be received. Now lift the paper, taking care not to touch the tray. Now with a proof plane touch the tray, and then place the proof plane on the cap of an electroscope, the gold-leaves of which were previously caused to diverge with + E. The leaves will diverge further, showing that the tray is electrified with + E. Now bring the knuckle near the edge of the tray; a spark will pass, and the tray will be discharged. The isolated tray and the brown paper form what is called an electrophoros.

Experiment 27. To make an electrophoros. Fasten a stick of sealing-wax to the middle of a sheet of tinplate with smooth edge. Beat a disc of vulcanized indiarubber or ebonite with cat's fur. Place the tinplate on the disc, touch it with the finger, and then raise it by its isolating handle. Bring the finger near the edge

of the tinfoil; a spark will be received, and the electrophorus discharged.

**NOTE 1.** The ebonite became charged with  $-E$ . This acted by induction upon the tinfoil, separating the natural  $+E$  and  $-E$ , attracting the former to the under side and holding it fast, and repelling  $-E$  to the upper side. The  $-E$  escaped through the body to the ground on placing the finger on the tinfoil; and on lifting the latter, the  $+E$  spread all over it, but escaped in its turn to the ground when the knuckle was presented to the plate.



The Electrophorus.

**NOTE 2.** A proof plane and sheet of brown paper (to be brushed with clothes-brush) form a good little electrophorus. So will a square of indiarubber and a halfpenny with small rod of sealing-wax stuck in its centre.

### DISTRIBUTION OF ELECTRICITY— INFLUENCE OF FORM.

**NOTE.** 1. On a sphere electricity is equally distributed over the surface.

2. On a disc (plate) round the edges.

3. On a cylinder around the edges at the two ends.

4. Generally on the outsides of bodies.

**Experiment 28.** Place a metal disc on varnished glass tumbler, and charge it by contact with excited glass

rod. Take proof plane and touch the centre of the disc with it, and then place proof plane on the cap of an electroscope. The leaves will diverge very slightly. Now touch the edge of the disc with another proof plane, and do the same as before; this time the leaves will diverge much further, showing that there was more electricity on the edge than in the centre of the disc.

**Experiment 29.** Isolate a tin saucepan by placing it on an inverted varnished glass tumbler, and electrify the inside by means of rubbed glass rod and proof plane. Now touch the inside with the latter, and place it on the cap of a gold-leaf electroscope; the leaves will not move, showing that, although the inside was charged, there is no electricity there. Now touch the sides, and try the electroscope as before; the leaves diverge. Next run proof plane round the edge of the saucepan, and again test; this time the leaves diverge much further than before, showing that while there is electricity on the outside of the saucepan, it is most abundant round the edges.

**Experiment 30.** Repeat the last experiment, and suspend a metal-covered ball by an earth-connected copper wire so that it shall hang within the saucepan without touching it. Now carefully touch the inside of the latter with a proof plane (taking care to touch nothing else), and place it on cap of the electroscope; the leaves will diverge, showing that the inside of the saucepan is now electrified. The reason of this is, that the + E on the saucepan acts by induction upon the ball, attracting - E and repelling induced + E to the ground. The - E on the ball attracts + E to the inside of the saucepan.

## THE ACTION OF POINTS.

**Experiment 31.** Electrify glass rod. Holding a needle in the hand a few inches from the rod, pass its point quickly from end to end on each side of the rod. Now hold the rod over an electroscope, and the leaves will not move, showing that the rod has been completely discharged. The rod was discharged in the following manner: The  $+E$  on the rod acted by induction upon needle and hand attracting induced  $-E$  to the point, from which it escaped in a stream, and mingled with the  $+E$  on the rod, and thus neutralized it.

**NOTE.** Lightning-conductors discharge electrified clouds passing over them in exactly the same manner, and thus prevent buildings to which they are attached being struck by lightning.

**Experiment 32.** Excite glass rod as before. Let fall towards it a strip of gold-leaf. At first the strip will move rapidly towards the rod, but before reaching it, will rebound as rapidly, being repelled. As before, the  $+E$  on the rod acts by induction upon the leaf, causing the near part to be negative and the far side positive. Then as the gold-leaf approaches, the induced  $-E$  being very strongly attracted (and the leaf having a very fine edge, which may be regarded in the same light as a point or a number of points), escapes, and the gold-leaf remains charged with  $+E$ . Hence, the glass rod being similarly electrified, the gold-leaf is repelled.

**Experiment 33.** Fasten a pointed wire to the  $+$  conductor of the electrical machine. When the handle is turned a wind appears to come from the point. Bring

a lighted candle near the point, and it will be blown out. Now try the same with the - conductor. The wind is not nearly so strong, and the candle will flicker, but will not be blown out. The reason of this difference is that positive electricity escapes from a point in a pencil-like stream, while negative is dispersed more widely like the rays from a star.

**Experiment 34.** Place a lighted candle on + conductor. A very small spark only will be obtainable, owing to the + E escaping from the pointed flame.

### THE ELECTRICAL MACHINE.

**Description.** The essential parts are—

1. A smooth glass plate or cylinder, with winch for turning it.
2. Silk or leather rubbers.
3. Isolated prime conductors—one presenting points to the glass, and called the + conductor, and the other, connected with the rubber, called the negative conductor.

**Action.** When the handle of the machine is turned the glass is excited with + E, and the silk with - E by friction. The + E on the glass acts by induction upon the + conductor, attracting - E to the points, from which it escapes, and neutralizes the + E on the glass, and at the same time repelling the induced + E, which cannot escape on account of the isolation of the conductor. It therefore remains charged with + E until discharged. At the same time the - conductor, if isolated, will be charged with induced - E by the inductive action of the - E on the rubbers.

Leyden batteries may now be charged from either conductor.

### CONDENSATION OR ACCUMULATION.

**Def.** By condensation or accumulation is meant the storing up of the two electric fluids, by taking advantage of the attraction they have for each other.

**Experiment 35.** Fasten silk thread loops to the opposite edges of a square varnished glass plate. On a table lay an earth-connected wire, and upon it a sheet of tinfoil. Place the varnished glass, which should be larger than the tinfoil by about an inch all round, on the top of the foil, and on the glass another sheet of foil, the same size as the under sheet, and immediately opposite it. Pass a wire from the upper foil to the cap of a gold-leaf electroscope, and another from the upper foil to the + conductor of an electrical machine. Now turn the handle until the leaves begin to move, and then remove the wire from the machine with isolator to prevent a shock, and gently lift the glass plate by its silk loops. The leaves will diverge, for the following reason: When the handle of the machine is turned the upper foil receives a charge of + E from the + conductor. This + E acts by induction upon the tinfoil on the under side, attracting - E, and holding it fast to the under surface of the glass, and repelling induced + E through the wire to the ground. The + E on the upper foil and the induced - E on the under side are therefore attracting each other so as to disguise their existence as it were. The more + E the upper foil receives, the more - E it will induce on the under side; and thus the two electricities are condensed or accumu-

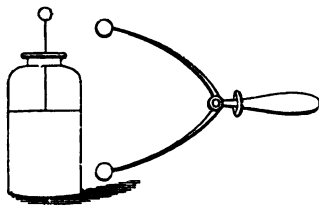
lated until the glass resists further inductive action, when the  $+ E$  on the upper side being no longer capable of acting inductively begins to cause the leaves of the electroscope to diverge. On lifting the glass plate a certain amount of  $- E$  on the under side escapes to the ground, there is thus an amount of  $+ E$  set free on the upper side which goes to the electroscope, causing its leaves to diverge further.

**Experiment 36.** Place a mahogany board on four varnished glass tumblers (isolating stool); on the board an earth-connected wire, on the wire tinfoil, then varnished glass plate, above that another sheet of tinfoil, connected by wire with the  $+$  conductor of the electrical machine. Turn the handle for a moment, and remove the earth-connected wire with the hand, as there is this time no danger of receiving a shock; then remove the upper wire with hand also. Lift glass with the upper foil, and with a proof plane and electroscope test the kind of electricity on both foils. On the upper will be  $+ E$ , and on the lower  $- E$ .

**Experiment 37.** Paste tinfoil on each side of plate of varnished glass, leaving a margin of about an inch all round (Franklin's plate or condenser). To the under foil fasten a strip of foil, roll it round a glass rod, and bring it round the edge of the glass to the upper side, so that by rolling backwards and forwards it may be made to approach and recede from the upper foil. This latter contrivance will act as a discharger. Now arrange as in the last experiment; that is, connect the upper foil with the  $+$  conductor of the machine, and the lower with the ground by means of wires. Now work the machine

until a spark passes between the two foils. Continue to turn the machine, and the sparks will be brighter and brighter, and the sound produced louder and louder as more and more electricity is condensed and discharged.

**NOTE.** The Leyden jar. Another form of condenser is the Leyden jar, so named from the town in which it was discovered. It consists of a glass jar, coated inside and outside with tin-foil to within an inch or two of the top, and surmounted by a brass nob in metallic connection with the inner coating.



The Leyden Jar and Discharger.

**To charge it.** Hold jar in the hand and let the knob rest against the + conductor of the electrical machine, a few turns of which will be sufficient to charge it; or hold the knob in the hand and let the outer coating touch the prime conductor. In the former case the inside of the jar will be positive, and the outside negative; while in the latter the inside will be negative, and the outside positive. The jar cannot be charged unless the side not in connection with the conductor is in connection with the ground.

**To discharge it.** 1. Place one hand on the outer coating, and touch the knob with the other hand. A shock will be experienced, and the jar will be discharged.

2. Take a pair of discharging tongs, and place one knob on the outer coating and the other on the knob of the jar.

A bright spark will pass between the two knobs, causing a loud report, and the jar will be discharged.

**The residual charge.** After waiting a little discharge the jar again. There will be a small spark and a faint report, due to some of the electricity which resided on the inner and outer surfaces of the glass not being all discharged on the first occasion. Sometimes a third and even a fourth discharge may be obtained. The reason of this is that the charge resides on the glass and not on the sheets of tinfoil, as may be shown by using a jar with movable coatings.

**Explanation of the charging of the jar.** The inside receives a charge of  $+E$  from the  $+$  conductor. This  $+E$  acts by induction through the glass upon the outside, separating the two electricities, attracting  $-E$ , and repelling induced  $+E$  through the body (or other conductor) to the ground. The more  $+E$  there is inside, the more induced  $-E$  there will be on the outside, until the glass resists further induction, when the jar is fully charged.

**The first form of the Leyden jar.** The first form of the Leyden jar was a water-bottle half filled with water, and resting on the hand. Into the water dipped a chain attached to the  $+$  conductor of an electrical machine. On attempting to remove this chain, after the machine had been worked, the experimenter received a shock. In this form, which led to the discovery of the Leyden jar, the water formed the inner and the hand the outer coating.

**Experiment 38.** Charge a Leyden jar in the usual way, and place it on the isolating stool. Touch the knob

with a proof plane, and place it on the cap of a gold-leaf electroscope charged with + E. The leaves will diverge further, showing that there was free + E on the knob. Touch the knob with the hand, and then try the outer coating with the proof plane. The leaves will now diverge less, showing that there is free - E on the outside. Now touch the outside with the hand, and it will be seen in the same way as before that there is more + E set free on the inside, and so on. The jar may be gradually discharged by touching the knob and the outer coating alternately, while the jar is isolated.

**Experiment 39.** Again charge the jar and discharge it by the discharging tongs. After waiting a few minutes test for the residual charge, either with the discharging tongs or with the two hands.

### THE SPARK.

**NOTE.** The electric spark is due to the passage of electricity through the non-conducting atmosphere. This passage of the electricity produces sound (the crack), light (the spark), and heat.

**Experiment 40.** To fire gunpowder by the spark. Place a little gunpowder on an earth-connected metal plate. By means of a discharger let a spark pass from the inner coating of a charged Leyden jar into the powder. The powder will be scattered, owing to the suddenness and rapidity of the discharge. Now hang a metal ball from one arm of the discharger by means of a wet string, and repeat the experiment. This time the powder will be fired, owing to the discharge being less sudden and rapid.

**Experiment 41.** To form the Leyden battery. Place four or six or more Leyden jars on a large sheet of tinfoil earth connected. The outsides of all the jars are thus connected with the earth. Now connect the knobs by means of metal rods, and connect one of the knobs with the + conductor of the machine. On working the machine, all the insides will be charged with + E, and all the outsides with induced - E. If there be six jars of equal size, the charge of the whole will be six times the charge of one. The whole battery may be discharged by connecting the knob of one jar with the outside coating of either the same jar or any of the others, and there will be a very loud report, and a very bright spark.

**Experiment 42.** To deflagrate platinum wire. Stretch a thin piece of platinum wire by means of two weights across a card. Let one of the weights be connected with the ground. Place one knob of the discharger on one of the knobs of a charged Leyden battery, and with its other knob touch the weight not connected with the earth. There will be a flash, and the platinum wire will disappear. It has been converted from a solid to a vapour by the heat produced by the discharge of the battery.

**Experiment 43.** The cascade battery. Isolate all the jars except the last, the outer coating of which must be connected with the ground. Let the knob of the second touch the outer coating of the first, the knob of the third the outer coating of the second, and so on; and let the knob of the first touch the prime conductor, having an electric gauge. Turn the handle

and the battery will be charged immediately. On discharging it, the spark will be no brighter than if only one jar had been used.

**NOTE.** The second jar is charged by the induced + E escaping from the first, the third by the induced + E from the second, and so on; consequently the whole battery will be but weakly charged.

### NATURE OF THE DISCHARGE.

**Experiment 44.** To show the rapidity of the spark. A humming-top with the seven colours painted on its upper surface appears white while spinning. In a dark room discharge a Leyden jar close to this top while in the act of spinning. By the light of the spark all the colours will be seen distinct as if the top were standing still. This shows the great rapidity of the spark.

**Experiment 45.** The formation of ozone. Moisten a piece of blotting-paper with a solution of starch and iodide of potassium, and hold it near to a point from which electricity is escaping; for example, the point of a pin attached to the charged + conductor of an electrical machine. The paper will be turned blue owing to the formation of ozone (a peculiar form of oxygen gas), which produces the blue iodide of starch.

**Experiment 46.** Beat ebonite plate with cat's fur. The ebonite will be electrified with - E. Trace the letter C on the ebonite with the knob of a charged Leyden jar. There will be + E where the knob has been. Now shake a mixture of red-lead and flowers of sulphur in a muslin bag over the ebonite plate. The

sulphur will go to that part of the plate which has + E, and the red-lead to the - E. The reason of this is that by friction the sulphur becomes negatively, and the red-lead positively, electrified; the former is consequently attracted by the + E, and the latter by the - E.

#### RELATION OF HEAT TO ELECTRICITY.

**Experiment 47.** To show that flame disperses electricity. Hold a lighted match over a charged electroscope; the leaves collapse.

**Experiment 48.** Heat iron ball white-hot, and lift it by isolating hook. Let it touch for a moment the charged + conductor of the machine, and then the cap of an electroscope. The leaves will not diverge, showing that when iron is white-hot it cannot be charged with + E. Now try the - conductor, and the same result will follow. As the ball cools it will be found that it will first take a charge of - E, and next one of + E.

**Experiment 49.** Heat an iron ball, and take it out of the fire with a conducting hook. Hold the ball first over a positively charged electroscope, and then over one charged with - E, keeping the ball at equal distances from the cap in both cases. Both electroscopes will be discharged. Charge them as before, and as the ball cools, it will be found that the ball retains the power of discharging the one negatively charged the longest.

#### ATMOSPHERIC ELECTRICITY.

##### Thunder and Lightning.

**NOTE.** There are often large quantities of electricity in the atmosphere caused by evaporation, which is always

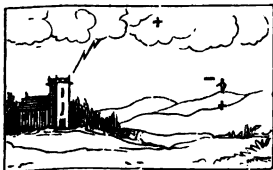
going on on the surface of the globe, by expansion and condensation of water vapour, and in a variety of other ways. The clouds act as immense prime conductors, and the air acts as an isolator, removing the clouds from electrical connection with the earth. When two clouds oppositely charged approach each other, they are discharged, enormous sparks (lightning) passing, accompanied by loud reports (thunder). When masses of thunder-clouds charged with, say,  $+E$ , approach the earth, this electricity acts by induction upon it, causing all objects on its surface, such as buildings, to be charged with  $-E$ . There is consequently produced an enormous condenser, the clouds and the surface of the ground acting like the two sheets of tinfoil, and the non-conducting atmosphere serving as the glass plate between. Should the clouds approach sufficiently near the earth, this great condenser is discharged, and then the lightning is very dangerous. To preserve buildings, lightning conductors are used. These are metal rods pointed at the top and projecting above the buildings, and well connected with the earth at their lower extremities.

**Experiment 50.** Let two strips of paper hang side by side from the charged  $+$  conductor of an electrical machine. The strips repel each other, both being charged with  $+E$ . Holding a needle in the hand present its point to one of the strips. They will immediately collapse, having been discharged by the stream of induced  $-E$  from the point of the needle. Now close the hand over the point, the strips will both move towards the hand; for having received another charge of  $+E$  from the conductor, they act on the hand by induction,

attracting  $-E$  and repelling  $+E$  through the body to the ground. As they approach, a spark passes between the hand and the strips. In this experiment the strips may be regarded as clouds charged with  $+E$ , the hand with the needle as a building with a lightning conductor, and the hand closed over the needle as a building not so provided. In the former case the cloud is discharged, while in the latter the building is struck by lightning.

**Experiment 51.** Isolate a long wooden rod, either by fixing one of its ends in a varnished glass tube or by wrapping it with vulcanized caoutchouc. To the other end fix a sponge dipped in alcohol (spirit). Connect the rod and electroscope with a thin copper wire. Light the alcohol, and bring the flame over a point fastened to the prime conductor. The leaves will diverge, because the flame of alcohol being a good conductor collects the  $+E$  as it escapes from the point. The  $+E$  flows along the wire to the gold-leaves, causing them to diverge.

**NOTE 2. The return shock.** In thunder-storms animals and men too have often been killed without being actually struck by the lightning, and at considerable dis-



The Return Shock.

tances from the place of discharge. Suppose a man to be standing on a hill at a distance of say one mile from a church spire, standing on an opposite hill. A cloud charged with  $+E$  lowers between these two objects. The  $+E$  in the cloud acts by induction upon the man, attracting  $-E$ , and highly charging him with it, and at the same time repelling induced  $+E$  to

the ground. Now suppose the cloud to be suddenly discharged, as it would be by striking the spire. The + E induced in the man, and repelled to the ground, suddenly returns to combine with the - E, giving the man a shock, which, if of sufficient force, will kill him.

**Experiment 52.** To light gas-jet by the return of induced electricity from the ground. Place a large isolated wooden packing-case in contact with the prime conductor. Stand near this isolated conductor, holding in the hand a wire just above a turned-on gas-jet. Let some one take a spark from the prime conductor, and a spark will at the same instant pass to the gas-jet and light the gas. The large conductor being positively charged, acted by induction upon the person's body, attracting - E and repelling induced + E to the ground. The body is thus highly charged with induced - E. On taking a spark from the conductor it is discharged, and the induced + E returning from the ground to recombine with - E on the body, passes as a spark between the gas-pipe and the wire and ignites the gas.

**NOTE.** Galvani's first observation. A frog, which had been recently killed, was lying on a table immediately under the prime conductor of an electrical machine. He noticed that every time a spark was taken from the conductor the limbs of the frog were convulsed. The + E on the conductor acted by induction on the frog's body, attracting - E and repelling induced + E to the earth. On taking a spark from the conductor the repelled + E returned from the earth to neutralize the - E in the frog's body, the nerves of which were susceptible to the shock they thus received. This shock was

the "return shock." For some little time after death the nerves of animals are capable of being influenced by electrical discharges.

### MAGNETIZING EFFECTS OF THE DISCHARGE.

**Experiment 53.** Lay a strip of tinfoil on a sheet of varnished glass, and lay one strip of steel above and another below the foil crosswise. From a charged Leyden battery send several sparks along the foil at right angles to the steel strips. Now examine them, and they will be found to be magnetized with the ends which were pointing in the same direction, north and south poles respectively. Notice the same result with the two nails, one above and the other below a wire through which a voltaic current is flowing.

# VOLTAIC ELECTRICITY.

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**Other names.** "Current Electricity," because it is supposed to flow like a current in a circuit; "Galvanic Electricity," or "Galvanism," from Galvani, formerly Professor of Physiology in the University of Bologna ("Voltaic," from Professor Volta of the University of Pavia).

## SIMPLE METHODS OF GENERATING A VOLTAIC CURRENT.

**Theory of electric currents.** This theory supposes that when the two poles of a voltaic battery are joined by a wire, a current of positive electric fluid flows from the platinum through the wire to the zinc outside the liquid, and from the zinc to the platinum inside; while at the same time there is an equal amount of negative electric fluid flowing in the opposite direction. The current is thus supposed to consist of two streams of the two fluids flowing in opposite directions in a closed circuit; but in speaking of the direction of the current, the course taken by the + fluid is alone referred to, the - fluid being, as a matter of convenience, left out of consideration. We do not know that there is such a thing as electric fluids—we only imagine it, as we do the existence of magnetic fluids.

**Experiment 1.** Dip a strip of pure platinum and

a strip of pure zinc into a jar containing brine (salt and water), or sulphuric acid and water, and connect the ends outside the liquid by a copper wire. Now dip the wire into iron filings, and a few of them will be attracted by it, showing that the condition of the wire is different from what it is at ordinary times; or in other words, showing that a current is flowing along the wire.

**Experiment 2. Sulzer's experiment.** Place a silver coin above the tongue and a small piece of zinc under it, and allow them to touch in front. A nauseous taste will at once be perceived. This taste is due to the chemical action which goes on, while a current is flowing from the silver to the zinc outside the tongue, and from the zinc to the silver inside.

**Experiment 3.** Dip a silver fork and steel knife into weak acid or brine, or stick them into any sour fruit, as an orange or lemon, and let them touch outside. A current of electricity will flow.

**NOTE.** To intensify the current in experiment 1. Take three or four jars similar to the one used in the first experiment. Connect by means of copper wires the platinum in the first jar to the zinc in the second, the platinum in the second to the zinc of the third, and so on, leaving a free zinc in the first jar or cell, and a free platinum in the last. Now connect these two free plates by means of a copper wire, and a much stronger current will flow along it, as may be shown by dipping it into iron filings, when a much larger number will cling to it.

## **MAGNETIC EFFECTS OF THE CURRENT.**

**Experiment 4. Iron filings attracted.** As

already described, dip the wire through which a current is flowing into iron filings, and they will be attracted.

**Experiment 5. Magnetic needle deflected.**

Set up a battery of three cells in such a manner that the wire connecting the extreme plates may run north and south. Now bring a small magnetic needle, horizontally suspended by means of a thread, over the wire. The needle will be deflected, or turned across the wire. If the current be flowing from N. to S., and the needle be above the wire, its N. pole will turn towards the W.; if below the wire, towards the E. If, again, the current be flowing from S. to N., the needle, if above, will turn E., and if below, W. The following lines should be committed to memory:—

Needle above wire, N. to S.—W.; S. to N.—E.

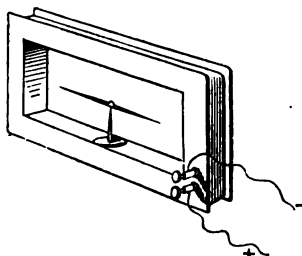
„ below „ N. to S.—E.; S. to N.—W.

**Experiment 6. Soft iron nails magnetized.**

Using battery mentioned in the last experiment, place a soft iron nail at right angles to wire above it, and another below. They should be quite close to the wire. Now test them with a small magnetic needle. They will be found to be magnetic; the upper one (supposing the current to be flowing from N. to S.) having its N. pole to the W., and the lower one with its N. pole pointing E. They have been magnetized by the inductive action of the current.

**NOTE.** The multiplying galvanometer. A much greater deflection of the needle may be obtained by passing the current through a multiplying galvanometer, so called because the action of the current on the

needle is multiplied by the number of folds of wire in the instrument. It consists essentially of a covered copper wire folded round and round a flattened hol-



The Multiplying Galvanometer.

low frame of ivory or ebonite, its two ends or terminals being connected with two binding screws. Within the coil is balanced a small magnetic needle; and when used, the coil of wire and the needle should both be in the magnetic meridian, with

the needle pointing to zero on a graduated disc below it. It may be used for testing the existence of weak currents, and also for comparing the strengths of currents.

Within certain limits the strengths of currents are proportional to the tangents of the angles of deflection of the needle. For example, try two currents, and let the first deflect the needle through  $60^\circ$  and the second through  $30^\circ$ . Then—

$$\frac{S_1}{S_2} = \frac{\tan 60^\circ}{\tan 30^\circ} = \frac{\sqrt{3}}{\frac{1}{\sqrt{3}}} = 3,$$

where  $S_1$  represents the strength of the first current and  $S_2$  the strength of the second. It will be seen from this example that the first current is three times as strong as the second.

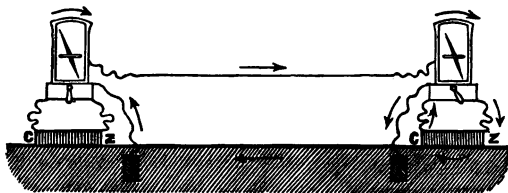
**NOTE 2.** The astatic galvanometer is an instrument for detecting the presence and measuring the strengths of feeble currents as well as strong ones. It is more delicate and sensitive than the common multiplying

galvanometer. It consists of a coil of insulated wire, within which is suspended the lower of two small magnetic needles rigidly connected by a thin strip of ivory or ebonite at their centres, with poles reversed. The upper needle moves over a graduated disc outside the coil. The whole is covered with a glass shade. The two needles are as equally magnetized as possible, and having reversed poles, the earth's magnetic action upon them becomes to a great extent neutralized. A very feeble current of electricity can therefore deflect them. Before using the instrument it should be so placed that the upper needle shall, under the earth's influence, point at zero on the graduated disc.

### THE NEEDLE TELEGRAPH.

The essential parts are—

- (1) A battery for generating the current ;
- (2) An insulated wire for conducting the current ; and
- (3) A signalling-machine, consisting of a multiplying galvanometer, provided with an instrument for reversing the current.



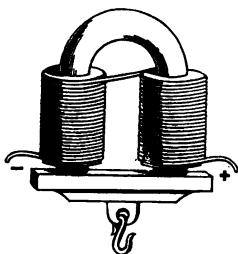
The Needle Telegraph.

Between any two telegraph stations, say London and Edinburgh, the circuit, which can be broken or established at pleasure by the current reverser, consists of the battery,

the wire (of which the signalling-machine forms a part), and the earth, which serves instead of a return wire. Connection with the earth is made by means of plates sunk deep in the ground at both stations.

**Experiment 7.** Bar or rod of soft iron magnetized. Coil an insulated copper wire (that is wrapped with silk) around a bar of soft iron from end to end, and connect the ends of the wires, one with the zinc and the other with the platinum plate of a battery. The soft iron bar will become magnetic (electro-magnet) by the induction of the current upon it. That end of the rod at which the current flows in the direction of the hands of a clock will be the S. and the other end the N. pole, as may be shown by a small magnetic needle. The coil of wire, after the bar has been removed, will attract and repel the needle in the same way that the bar did, or in other words, the polarity of the coil of wire will be the same as that of the iron bar.

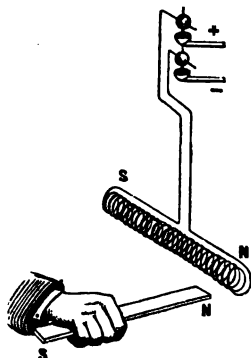
**Experiment 8.** To make a horseshoe of soft iron into an electro-magnet. Take a piece of insulated copper wire and coil it round one of the arms of the horseshoe of soft iron in a left-handed helix. After making the helix double by coiling in the same direction, pass over to the other arm, and coil the wire in a right-handed helix backwards and forwards once. Connect the ends of wire with the two plates of a voltaic battery, and the horse-



The Electro-Magnet.

shoe will become a strong magnet by the induction of the current.

**Experiment 9. The floating battery.** Pass the free ends of a small helix or solenoid of covered wire inwards, and let them both pass between two folds in the middle, and thence through a large flat cork. To one end of the wire fasten a small plate of amalgamated zinc, and to the other end attach a piece of copper of the same size as the zinc. Float the whole in a vessel containing water rendered sour by the addition of a little sulphuric acid. A current will flow through the helix; and the latter will settle in the magnetic meridian, just like the horizontal needle, that end at which the positive current flows in the opposite direction to that in which the hands of a clock move (or in a left-handed direction), pointing N. To this end bring the N. pole of a permanent magnet, and the coil will be repelled; now bring the S. pole to the same end, and it will be attracted. In this way a wire through which a current is flowing can be made to behave just like the horizontal magnetic needle.



Ampère's Stand.

**NOTE.** The same result can be produced by using Ampère's stand (as above) instead of the floating battery.

### ATTRACTION AND REPULSION OF CURRENTS.

**Experiment 10.** To show that currents flowing in the same direction attract, and in opposite directions repel each other. Make two flat spirals of covered wire, and connect one end of one with one end of the other, face to face, and in such a manner that a current will flow in the same direction through both. Suspend the pair by silk thread, and connect the free ends with the two poles of a battery. A current will flow, and the two spirals will attract each other. Now reverse one of them so that the same current will flow through them in opposite directions. The spirals will now repel each other.

**Experiment 11.** Suspend an open spiral of elastic wire so that its lower end will dip into a cup of mercury connected with one pole of a battery. Now connect the other end of the spiral with the other pole. The wire will at once jump out of the mercury, on account of the folds of the spiral (through all of which the current flows in the same direction) attracting each other, and thus shortening the coil.

**NOTE.** By these experiments is demonstrated the law that currents flowing in the same direction attract, and in opposite directions repel each other.

### CHEMICAL EFFECTS OF THE CURRENT.

**Galvani's second observation.** The legs of a frog recently killed had been hung by a copper hook on an iron railing. Moved by the wind, the legs occasionally

touched the iron railing, and Galvani observed that every time they came in contact with the iron the legs were convulsed. There were here the three elements of a voltaic cell, namely, two metals and a liquid (that contained in the frog's limbs). Chemical action took place, and a momentary current of electricity was set up, which produced the shock.

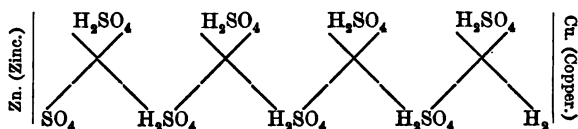
**Experiment 12.** Amalgamate a piece of zinc by first dipping it in dilute sulphuric acid and then rubbing it over with mercury. This prevents what is called local action. Place the amalgamated zinc along with a similar-sized plate of copper in a flat dish containing dilute sulphuric acid. Before the plates touch one another no action will be observed. Now allow them to touch, and bubbles will at once be seen to rise from the copper plate. These are bubbles of hydrogen gas.

**Experiment 13.** Now take the same plates, and place them in a jar containing the same liquid (one part of sulphuric acid added to eight or twelve parts of water). Connect the plates outside the liquid by means of a wire. Bubbles will begin to rise from the copper plate.

**NOTE.** The following is what may be supposed to take place when the two plates are connected outside the liquid :—

1. **Chemically.** The sulphuric acid attacks the zinc, forming a salt called the sulphate of zinc, which dissolves in the water as fast as it is formed, while hydrogen gas is set free. This gas, which is first set free at the zinc plate, does not make its appearance there, but is taken up by the next molecule (particle) of sulphuric acid, which in turn yields up its hydrogen to the next molecule,

and so on, the last particle of hydrogen coming off when it reaches the copper plate. The chemical formula for sulphuric acid is  $H_2SO_4$ , the meaning of which is that every molecule or smallest particle of sulphuric acid contains one atom of sulphur (S), four atoms of oxygen gas ( $O_4$ ), and two atoms of hydrogen ( $H_2$ ). The following diagram may then represent what takes place:—



where the upper row of symbols represents the arrangement of the molecules **before**, and the lower row **after** the plates are connected.

**2. Electrically.** A current of + E flows from the copper to the zinc outside, and from the zinc to the copper inside the cell, while at the same time an equal current of - E flows in the opposite direction. In speaking of the direction of the current we refer to the course taken by the + E only.

After the two metals were dipped in the liquid, but before they were connected together, the zinc plate was electrified with - E outside and with + E inside the liquid, and the copper with + E outside and - E inside. On joining them together, chemical action set in, and a force called the **electromotive force** came into play, which drove the + E and - E in opposite directions in the circuit.

**Def. Electromotive force** is that force within a

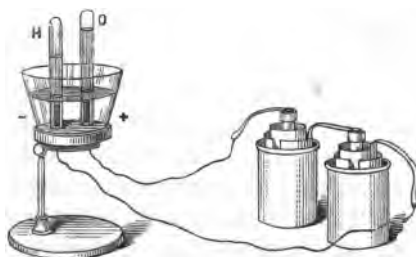
voltaic battery which separates the two electricities and drives them in opposite directions in a circuit.

**Def.** A circuit is the course taken by the electric current.

**Experiment 14.** Allow a voltaic cell which has been used for some time to stand for a day or two. It will be found to contain a whitish salt. This salt is the sulphate of zinc.

Electrolysis is the decomposition of a chemical compound by the voltaic current.

The **voltameter** is an instrument used for the electrolysis of water. The word is derived from "Volta" and the Greek *metron*, a measure. It consists of a glass vessel in the bottom of which are fixed, about a couple of inches apart, two plates of the metal platinum connected with two binding screws fixed on the under side of the vessel. These two binding screws are to receive the ends of the wires from the two poles of a battery.



The Voltameter.

**Experiment 15.** Pour water into the voltameter, and add a few drops of sulphuric acid. Over the two

platinum plates (called the electrodes) invert two glass test-tubes of equal size, previously filled with water and a little acid. Connect the two terminal wires of a strong voltaic battery with the two binding screws. The current passes through the water, entering by the electrode connected with the platinum pole, and called the + electrode, and leaving the vessel by the - electrode, or that connected with the zinc pole of the battery. The water is decomposed into oxygen, which rises into the tube over the + electrode, and hydrogen, which comes off at the - electrode. The hydrogen tube will be found to fill twice as fast as the oxygen tube. This is owing to the composition of water, which consists of two volumes of hydrogen in chemical combination with one volume of oxygen. It is found that in reality there is a little more than twice as much hydrogen as oxygen, owing to the fact that the latter gas is more readily dissolved in water than the former. The chemical symbol for water, then, is  $\text{OH}_2$ , which means that every particle or molecule of water consists of one atom of oxygen combined with two atoms of hydrogen.

**Properties of oxygen and hydrogen.** Both are gases, colourless, tasteless, and without smell.

Hydrogen is the lightest element in nature. It will burn, but will not support combustion, as may be shown by inserting a lighted taper upwards into the test-tube containing it. The light will go out, but the gas will burn with a pale, hot flame at the mouth of the tube.

Oxygen is sixteen times heavier than hydrogen. It will not burn, but is a powerful supporter of combustion. Into the test-tube containing it put a glowing match. It

will burst into flame, but the gas will not burn at the mouth as the hydrogen did.

If the two gases be mixed together in a glass jar in the proportions in which they come off at the two electrodes, that is, one volume of oxygen and two volumes of hydrogen, and a light be applied to the mouth of the jar, there will be a loud explosion, and the glass jar will become dim. The two gases have recombined to form water, which has caused the dimness of the glass.

**Experiment 16. Polarization.** After the voltmeter has been used for some little time, disconnect the battery wires and connect the two electrodes with the two terminals of a delicate multiplying galvanometer. The needle will be deflected in such a way as to show that a current is flowing from the - to the + electrode within the voltmeter. (The effect of this current would be to weaken the one from the battery.) Hydrogen gas has been deposited on the negative, and oxygen on the positive electrode, and the platinum plates have been thus practically converted into hydrogen and oxygen plates. In other words, they have been polarized or have received the property of becoming the two poles or plates of a battery.

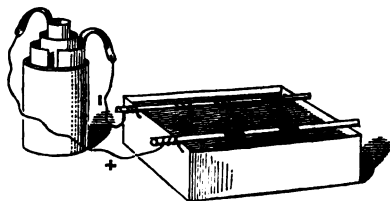
**NOTE.** Various compound substances called salts can be decomposed into metals and acids of which they are composed by electrolysis; for example, sulphate of copper, nitrate of silver, sulphate of iron, acetate of lead, etc. In every case the metal is deposited on the negative electrode, and the acid makes its appearance at the positive electrode.

**Electroplating.** The commoner metals, such as

copper, may be plated with silver or gold by means of electrolysis.

**To plate with silver.** The apparatus required consists of a porcelain trough or bath, with two parallel metal rods, from which electrodes can be suspended so as to dip into the liquid of the bath, and to which can be connected the two poles of a voltaic battery. The bath must contain two parts of cyanide of silver, and two parts of cyanide of potassium, dissolved in about 250 parts of water. A silver plate attached to the rod connected with the positive pole of the battery is immersed in the liquid, while the article to be plated is attached to the other rod and similarly immersed. The silver salt is decomposed, and metallic silver is deposited on the article to be plated, which forms the negative electrode. The silver plate is attacked by the acid set free, and the salt is kept at its full strength, and the negative electrode is plated at the expense of the silver plate, which forms the positive electrode.

**To plate with gold.** The action is similar to that of silver-plating, but in this case a plate of gold must take the



The Electroplating Apparatus.

place of the silver plate as the + electrode, and the salt

chloride of gold must be used in place of the cyanide of silver.

**Experiment 17.** Between the two platinum plates of a voltameter fit a thick pad of blotting-paper so as to divide the vessel into two separate compartments. Into both divisions pour a solution of sulphate of soda, coloured blue by adding a little litmus. Add a drop or two of acid to the liquid in one division; this will colour it red. Connect the negative pole of a voltaic battery with the platinum plate immersed in the red liquid, and the positive pole with that in the blue. The colours will be changed, the blue becoming red and the red blue. Now change the wires again, connecting the negative pole with the red and the positive with the blue. Again the colours will change, and so on.

The reason of these changes is as follows: The sulphate of soda is decomposed by the current from the battery, the metal sodium being set free at the negative electrode and the acid (sulphuric) at the positive. It is the property of an acid to redden blue litmus, and it is the property of sodium (an alkali) to restore the blue colour to reddened litmus. Hence the blue liquid which surrounds the positive electrode is reddened, while the red liquid in which the negative is immersed is turned blue.

**Chemical action in Grove's battery.** A cell in Grove's battery consists of (1) a porcelain jar containing dilute sulphuric acid in which is immersed a hollow cylinder of amalgamated zinc; (2) inside the hollow zinc cylinder a porous cell containing strong nitric acid and a plate of platinum. When the two plates are connected

by a wire the following chemical action takes place: The sulphuric acid ( $H_2SO_4$ ) combines with the zinc, forming sulphate of zinc, setting free hydrogen, which eventually passes through the porous cell and attacks the nitric acid, changing it into nitric peroxide (a gas) and water. The hydrogen therefore does not reach the platinum plate, which is thus prevented from becoming polarized. In the ordinary zinc and platinum cell, where only one liquid is used, hydrogen is deposited on the platinum, and the current weakened by a secondary current being established in an opposite direction.

Bunsen's cell resembles Grove's, but has a block of hard carbon instead of a plate of platinum. The chemical action in this cell is the same as that in Grove's.

Daniell's constant battery. This only differs from Grove's and Bunsen's in having a copper plate immersed in a strong solution of sulphate of copper, instead of platinum or carbon in strong nitric acid. The hydrogen passes through the porous cell as in the case of Grove's battery, but changes the sulphate of copper into sulphuric acid, and deposits copper on the copper plate. Thus the copper plate is plated with copper, and is not polarized as it would be if hydrogen were deposited upon it. Hence it is called the constant battery, because the current is not weakened by polarization.

**NOTE.** This is an example of the electrolysis of a salt in the battery which generates the current.

### HEATING EFFECTS OF THE CURRENT.

**Experiment 18.** Pass the current from the same battery successively through thin wires of silver, copper,

and platinum. The silver will be scarcely warmed, the copper will feel slightly warm, while the platinum will become red-hot ; owing to the fact that silver and copper are good conductors (silver better than copper), while the platinum being a less perfect conductor offers such resistance to the passage of the current as to produce heat enough to make the wire glow.

**Joule's law.** The heat produced in any part of a circuit is proportional to the square of the current strength multiplied by the resistance ; thus calling the former  $C^2$ , the latter  $R$ , and the heat produced  $H$  ; then,

$$H = C^2R.$$

### INDUCED CURRENTS.

**Experiment 19.** Lay a flat spiral of insulated copper wire upon a table. Connect the free ends of the wire with the two terminals of an astatic galvanometer. Within the inner circle of the coil introduce the N. pole of a permanent magnet. A *momentary* current will be induced in the wire deflecting the needle in such a way as to show that the induced current flows in the direction of the hands of a watch. Remove the magnet ; the needle will be momentarily deflected in the opposite direction, showing that a momentary current has been induced flowing in the opposite direction to the motion of the hands of a watch. Repeat the experiment, this time using the S. pole of the permanent magnet.



## SUBJECT IX.—MAGNETISM AND ELECTRICITY.

### FIRST STAGE OR ELEMENTARY COURSE.

#### Magnetism.

*General properties of magnets.*—Attraction of iron. Action of magnets on each other. Distinction between poles. Position of equilibrium of suspended magnet. Magnetic axis of a magnet. Magnetic meridian; Declination; Inclination (Dip). Names of poles. Behaviour to one another of like-named and unlike-named poles.

*Magnetic induction.*—Effect of a magnet on a neighbouring piece of soft iron. Diminution of the effect with increase of distance. Comparison between the effects on hard steel and on soft iron.

*Permanent magnetization of hard steel.*—Distribution of magnetism in magnets as inferred from the result of breaking them. Differences between the properties of different magnets depending upon their size, shape, and degree of magnetization.

*Terrestrial magnetism.*—Mariner's compass and dipping needle. Their behaviour at different parts of the earth. General explanation of the behaviour of compass and dipping needle on the assumption that the earth is a magnet.

#### Frictional Electricity.

Electrification by friction. Two distinct electrical states and their mutual relations. Positive and negative electrification. Simultaneous and equal development of the two electrical states. Action of electrified bodies on each other. Conductors and non-conductors. Effect of connecting a conductor with the earth. Experiments illustrating the relation between a primary electrical charge and the correlative induced charge. The Leyden jar and similar arrangements. Distribution of electricity on conductors. Action of points. Properties of hollow conductors. Frictional electrical machines. Electric discharge.

#### Voltaic Electricity.

Difference between the electrical conditions of two copper wires connected, one with a piece of zinc, the other with a piece of platinum or

copper, the platinum or copper and the zinc both dipping into the same vessel of dilute sulphuric acid. Result of connecting the copper wires with each other. Description of the most common forms of voltaic cell. Connection of cells in series to form voltaic battery. Increased difference of electrical conditions of terminal wires of a battery as the number of cells is increased. Evidence that this difference is of the same kind as that between the prime conductor and the rubber of a machine. Production of currents of electricity through conductors joining the terminals of a battery.

*Properties and effects of electric currents.*—Evolution of heat, influence upon magnetic needles, magnetization of soft iron, chemical action (a) inside the battery, (b) outside (electrolysis). Induced currents, their direction and duration. Current in the battery. The astatic galvanometer and its application to the detection of weak currents.

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*CLASSIFIED LIST of Examination Questions set by  
the Science and Art Department for the Years 1870-  
1882.*

**MAGNETISM.**

**The Loadstone or Natural Magnet.**

1. Tell me what you know about the loadstone or natural magnet.
2. Describe how you would impart the magnetic power of the loadstone to a piece of steel.
3. State all you know regarding the composition and the action of the loadstone or natural magnet.

**Magnetic Polarity.**

1. A magnet is broken in two, describe the magnetic conditions of its parts.
2. State the grounds of belief that the smallest particles of a magnet are themselves perfect magnets.
3. A steel sewing needle is drawn over the north pole of a magnet from eye to point, what is the subsequent condition of the needle? The point is presented to the north end of a mariner's compass needle, what occurs?

4. Supposing you break the sewing needle, referred to in the last question, in two, and present the two ends of each half in succession to the north end of a mariner's compass needle, what occurs?
5. What do you understand by the polarity of a magnet?
6. Can you obtain a magnet with a single pole? Give the experimental grounds of your answer.
7. You are required to magnetize a sewing needle, so as to make the eye end of the needle a north pole, how will you do it?
8. A long strip of hard steel is magnetized, and when your small magnetic needle is passed along the strip, its north point is attracted by one end of the strip, its south pole by the other, the centre of the strip appearing to attract neither point of the needle. When the strip is broken across at the centre, what is the action of its two halves upon the magnetic needle?
9. You have a steel bar magnet, and a steel knitting needle one end of which has been notched with a file. Describe exactly what you would do in order to magnetize the knitting needle in such a way that, when hung by a fine thread fastened to the middle, the notched end of the needle shall turn southwards.
10. A magnetized steel knitting needle is broken into three equal pieces. Would all the three pieces be equally magnetized? If not, how do you suppose they would differ, and why?

### Attraction and Repulsion.

1. You are required to demonstrate the law that like magnetic poles repel, and that unlike poles attract each other, how will you do it?
2. A bar magnet, freely suspended horizontally, sets in the magnetic meridian. Supposing a second bar magnet to be suspended by the side of the first, how will they act upon each other? Make your answer clear by a diagram.
3. Two small bar magnets are so suspended from their ends as to hang parallel to and at a short distance from each other. Their lower ends, which we suppose to be on the same level, are both north poles. Show by a sketch how they will act upon each other. Show also how they will act when one pole is north and the other south.
4. Two sewing needles are magnetized so that the eye of each is a north-seeking pole. The needles are stuck by their points into separate bits of cork, so that when thrown into water they float upright with the eyes downwards. How will they behave towards each other when floating in this way?
5. You are doubtful whether a steel rod is neutral or is slightly magne-

tized ; how could you find out by trying its action upon a compass needle?

6. By what experiments could you ascertain whether a sewing needle is or is not slightly magnetized?

### **Earth's Magnetism.**

1. What is meant by the declination and inclination of the magnetic needle? What is meant by the terms magnetic dip, magnetic poles, and magnetic equator?
2. You carry with you a dipping needle from the earth's north magnetic pole across the equator to the south magnetic pole, how will the dipping needle behave during this excursion?
3. What is meant by the terms declination and inclination as applied to magnetism?
4. The marked end of a magnet is attracted by the earth's north magnetic pole ; but if the magnet be set floating on a cork, it does not move towards the pole. Why?
5. You possess a small magnetic needle, with the end which points to the north marked N. and that which points to the south marked S. An iron poker, which has been perfectly annealed, is placed upright, and the magnetic needle is brought first near the bottom of the poker, and then gradually raised past the centre to the top. The poker acts upon the needle, and you are required to describe its action. (I must be sure that you understand what is meant by a perfectly annealed iron poker.)
6. It is sometimes said that the earth has no tendency to impart to a magnetic needle a motion of translation, but that it has under certain circumstances a tendency to impress upon it a motion of rotation. What is the meaning of these statements?
7. When a magnetic needle is suspended horizontally in London, in what direction will it point? You are to show here that you understand the difference between the geographical meridian and the magnetic meridian.
8. In what direction does the mariner's compass needle point in London?
9. What is the meaning of the term geographical meridian? What is the meaning of magnetic meridian? What name is given to the angle between the two meridians?
10. If a long bar of very soft iron is held upright, how is it that its upper end repels the south-seeking end of a compass needle and that its lower end repels the north-seeking end of a compass needle?
11. Explain why it is that although a magnetized steel needle floating

on water turns so as to point towards magnetic north and south, it does not move bodily in either of these directions.

12. If you were required to make a model to illustrate the magnetic properties of the earth by putting a bar magnet inside a ball of clay, show by a sketch how you would place the magnet, and explain how the magnetic properties of the model would answer to those of the earth.

### **Coercive Force.**

1. What is the meaning of the term coercive force? You are required to illustrate its action by naming some substances which possess it in a high degree, and others which possess it in a low degree.
2. State what is known to you regarding the difference between iron and steel as regards the acceptance and retention of magnetism.
3. The pole of a magnet is brought within an inch of one side of a sphere of very hard steel suspended from a string. It manifestly attracts the steel, but is not quite able to draw it into contact. A sphere of iron of the same weight is now substituted for the sphere of steel, and the magnet is found able to draw this new sphere quite up against itself. Explain this difference of action.

### **Theory of Magnetic Fluids.**

1. The pole of a magnet is drawn over an unmagnetized bar of steel; state in the language of the theory of magnetic fluids what occurs.

### **Induction.**

1. Near a ball of perfectly annealed soft iron the north end of a strong steel magnet is placed, what is the action of the magnet upon the ball? What change occurs in the ball when the magnet is withdrawn, and what occurs when the south pole of the magnet, instead of the north, is placed near the ball? Illustrate your answers by diagrams.
2. A bar magnet is held vertically and two equal straight bits of soft iron wire hang downwards from its lower end. The lower end of each of these wires can by itself hold up a small scrap of iron; but if the lower ends of both wires touch the same scrap of iron at the same time, they do not hold it up; what is the reason of this?
3. What is the magnetic condition of a bar of soft iron held near to and parallel with a bar-magnet?

4. Why is less force required to pull a small iron rod away from the poles of a powerful horseshoe magnet than would be required to pull a thick bar of iron away from the poles of the same magnet?

### **Magnetic Curves.**

1. Two bar magnets are placed upon a table parallel to each other, and with their north poles turned in the same direction. Over the magnets is placed a sheet of glass, and over this again a sheet of smooth paper. From a little sieve you carefully scatter iron filings over this paper. Show by one sketch the manner in which the filings will arrange themselves, and show by another sketch the change that occurs in the arrangement of the filings when one of the magnets is reversed.
2. A strong bar magnet is set upright and a sheet of cardboard rests horizontally on the top of it. Describe and show by a sketch the way in which iron filings sprinkled on the cardboard arrange themselves.

### **FRICTIONAL ELECTRICITY.**

#### **Attraction and Repulsion.**

1. You are required to prove, by experiment, the electrical law, that bodies similarly electrified repel; and that bodies dissimilarly electrified attract each other; how will you do it?
2. What is the action of two electrified glass tubes upon each other? What is the action of two electrified gutta-percha tubes upon each other? What is the action of an electrified glass tube upon an electrified tube of gutta-percha?
3. You are required to give an experimental proof of the law that bodies oppositely electrified attract each other, and bodies similarly electrified repel each other. Tell me the substance you would choose, and the manner in which you would use them to obtain the desired result.
4. A strip of paper rubbed with indiarubber is brought near to a glass rod which has been rubbed with silk; what follows? Deduce from this experiment the quality of the electricity on the paper.
5. A stick of sealing-wax is rubbed with dry flannel and held over a pith ball lying on a table. The ball rises to the sealing-wax and then falls again. Why does it rise, and why does it fall?

Two Kinds of Electricity.

1. When you rub a stick of sealing-wax with flannel, what is the state of the rubber? When you rub a stick of glass with silk, what is the state of the rubber?
2. Show by a simple experiment that the electricity developed on resin by the friction of flannel is different from that developed on glass by the friction of silk.
3. There are two kinds of electricity, called positive and negative. You rub sealing-wax with flannel; are both electricities excited, or are they not? If both, where? If only one, where?
4. You are required to electrify strongly a glass tube, how will you do it? You are required to electrify strongly a tube of gutta-percha, how will you do it?
5. When a piece of sealing-wax and a piece of dry flannel are rubbed together, one becomes positively electrified and the other negatively electrified. When a piece of dry paper and a piece of indiarubber are rubbed together, one becomes positively electrified and the other negatively electrified. How could you find out which of the four things—sealing-wax, flannel, paper, indiarubber—are in the same electrical state?
6. If two insulated bodies A and B are rubbed together and A becomes positively electrified, what is the electrical condition of B? (1) As to the kind of its electrification; (2) as to the amount of its electrification as compared with that of A.
7. Describe experiments which show that the terms *vitreous* electricity and *resinous* electricity are inappropriate.

Conduction and Isolation.

1. If you rub a stick of sealing-wax held in the hand with flannel it becomes electrified; if you rub a rod of brass, you do not electrify it. What is the reason of this difference?
2. I hold a dry glass rod which has been rubbed with silk near a brass ball which is supported on a dry glass stand; what is the state of the ball? Supposing the stand which holds the brass ball to be moist instead of dry, what will occur?
3. Two strings are given to you, and you are required to test whether they insulate or conduct electricity; how will you do it?
4. You touch the ball furthest from the sealing-wax in question 2 of induction, remove your hand, and then the sealing-wax; what is now the electric condition of the balls and chain? You must state what occurs at each step of the process.

5. What is meant by the terms conduction and insulation as applied to frictional electricity? Describe an experiment which shall illustrate the properties of metal wire, common twine, and a silk string, as regards conduction and insulation.
6. Give a clear definition of the terms electric conduction and induction.
7. An apple held in the hand, and struck with a fox's brush, shows no signs of electrical action; suspended by a string of silk, and struck with the brush, it becomes electrified, attracting light bodies, and causing the leaves of the electroscope to diverge. Explain these results.
8. Arrange the following substances in the order of their conducting powers for electricity, putting the name of the best conductor first: air, copper, glass, iron, sea-water, shellac, water (pure), wood.
9. How is it that you do not get a shock on touching the knob of a charged Leyden jar which stands on a cake of resin?
10. You have several rods of unknown materials. Describe exactly experiments which would enable you to distinguish those of them which are conductors of electricity from those which are non-conductors.
11. Could an electrical machine be made to act if it had a metal plate instead of a glass plate? If not, why not? If it could, show how.

### Induction.

1. Explain fully what takes place when light bodies are attracted by sealing-wax rubbed with flannel.
2. Two brass balls supported on glass stands are united by a chain; a stick of sealing-wax rubbed by flannel is brought near one of the balls; what is the condition of the other?
3. An eggshell is placed on a table, and a glass rod which has been rubbed with silk is brought near to the shell; the shell rolls after the rod. Describe the condition of the rod and shell during the motion of the latter.
4. A stout stick of sealing-wax is stuck upright to a piece of wood, acting as a base, into the wax at the top is inserted a needle, and on to the needle is fixed an apple; near to the apple, but not in contact with it, is brought a rod of glass which has been rubbed by silk. What is the condition of the apple while the rod remains near it? What occurs when the apple is touched for a moment? What finally occurs when the rubbed glass is withdrawn?
5. A lath six feet long is supported at its centre on a dry glass tumbler.

## *Examination Questions.*

71

Below one end of the lath, and at a distance of some inches from it, are placed some scraps of gold-leaf or other light bodies. A glass rod electrified by friction is brought over the other end of the lath, without touching it; the fragments of gold-leaf are immediately attracted. How is this attraction produced?

6. Supposing you were required to develop induced electricity, and to prove its existence, how would you do it?
7. A collodion balloon simply stroked with the hand becomes negatively electrified. Supposing you were asked to prove the truth of this statement, how would you proceed?
8. If you want to find out whether a body is electrified by seeing how it acts on an electrified pith ball hung by a silk thread, why is it a surer test that the body is electrified if it repels the pith ball than if it attracts it?
9. Show why it is necessary, in order to obtain a succession of sparks from the prime conductor of an electrical machine, that the rubber should be connected with the ground.

### **Theory of Electric Fluids.**

1. When you think of an electrified body, in what way do you picture it in your mind?
2. Give a sketch of the theory of electric fluids.
3. You are required to explain, in accordance with the theory of electric fluids, how light bodies are attracted by a glass rod positively electrified, and by a gutta-percha tube negatively electrified.

### **Electrophoros.**

1. Describe the electrophoros, and the mode of charging it.
2. I stick a bit of sealing-wax against a penny or half-crown, and I whisk a bit of vulcanized indiarubber with a fox's brush. Holding the sealing-wax as a handle, I lay the penny or half-crown flat on the indiarubber, what is the condition of the coin? I touch the coin, what occurs? I lift it by the handle, what is its condition?
3. What occurs when you whisk the resinous plate of an electrophoros with a fox's brush? The plates being excited, how will you obtain the spark of the electrophoros?
4. A piece of dry brown paper, laid on a warm metal tray, is rubbed with catskin. The tray is then placed on a dry glass tumbler, and the brown paper is removed. Explain how it is that you can now get a spark on bringing your knuckle near the tray.

5. If you have a penny-piece fastened to the end of a stick of sealing-wax, how could you give it a negative charge by help of a positively charged glass rod?

#### Action of Points.

1. A thunder-cloud, charged positively, comes over a pointed lightning conductor. The cloud gradually loses its charge of electricity by the action of the conductor. How is this accomplished?

#### Distribution.

1. A pewter pot is insulated and electrified, if you touch it at different parts with a penny stuck to the end of a rod of sealing-wax, what part of the pot will give the greatest quantity, and what part the least quantity of electricity to the penny?

#### Condensation.

1. Describe Franklin's plate, and explain its action.
2. You are required to charge and discharge a Leyden jar, how will you do it?
3. Describe the Leyden jar, and the mode of charging it.
4. You are required to make a small Leyden jar, how will you proceed?  
You are required to charge the jar when made, how will you do it?
5. You are required to explain fully what occurs during the charging and discharging of your Leyden jar.
6. Describe an experiment which shall illustrate the action of the electric condenser.
7. Describe a Leyden jar and the method of charging it.
8. One person holds a charged Leyden jar in his hand by its outer coating, and another holds similarly an uncharged jar. What happens when the knobs of the two jars are brought together?

#### Atmospheric Electricity.

1. How do you suppose thunder and lightning to be produced?

#### Electroscope.

1. Describe and explain the action of the common gold-leaf electroscope.

2. If on a warm board a sheet of paper be rubbed with indiarubber it is electrified. How is this proved?

**General.**

1. From what is the word electricity derived? Describe the substance with which the first electrical effects were observed, and describe the mode of exciting it.

**VOLTAIC ELECTRICITY.**

**Generation of the Current.**

1. I dip a strip of pure platinum and pure zinc into water which has been rendered sour by sulphuric acid. State what occurs when the metals do not touch, and also what occurs when they do touch each other.
2. Supposing the two strips to be half in the sour water and half out of it, and that their two outer ends are united by a wire, what occurs?
3. I give you platinum, zinc, and brine, and ask you to produce by means of them an electric current; how will you do it?
4. You are required to generate a voltaic current; how would you do it? How would you prove that you have really succeeded in producing a current?
5. A plate of platinum and a plate of amalgamated zinc are immersed in water rendered sour by sulphuric acid. Describe accurately, and explain what is observed both before and after the plates are caused to touch each other.
6. A steel knife and a silver fork are set upright in a vessel containing a solution of common salt, the steel and the silver are connected by a copper wire, state what occurs within the vessel and without it when the connection is made.
7. Describe the simplest means known to you whereby a voltaic current can be generated.
8. If a strip of pure platinum and pure zinc be immersed in acidulated water, and caused to touch each other, bubbles of gas are seen rising from the platinum, and not from the zinc. Explain this effect.
9. I place a bit of silver on my tongue, and a bit of zinc under it, and cause the two pieces of metal to touch each other, what occurs?

Describe some means of proving that an electric current is generated.

10. A current means something flowing. What is it that flows in the voltaic current, is it anything that you can see, or feel, or taste, or smell? If not, what proofs have you of its existence?
11. What is your notion of a voltaic current?
12. Supposing you wished to intensify the current obtained by the simplest means in answer to question 7, how would you do it?
13. Explain what you understand by the direction of a voltaic current.
14. You have a glass jar containing dilute sulphuric acid, into which a piece of zinc and a piece of copper dip without touching each other; how would you connect the zinc and copper, by means of wires, with a poker so as to make an electric current pass through the poker from the handle to the point? Give a drawing.
15. When a plate of zinc and a plate of platinum connected by a wire are both dipped into the same vessel of dilute sulphuric acid, an electric current passes along the wire. State and account for the effect of moving one of the plates into a separate vessel of acid.
16. State what happens when a piece of iron and a piece of copper dipping into dilute sulphuric acid contained in the same vessel are made to touch one another.

### **Magnetic Effects of the Current.**

1. Supposing the wire that connects the two ends to be dipped into iron filings, what occurs? Supposing it to be coiled round an iron poker, what occurs?
2. If the wire be placed over a freely suspended magnetic needle, tell me exactly what occurs.
3. Give me a clearly described example of the magnetic action of an electric current.
4. Suppose you wind an insulated wire round a poker, and send a voltaic current through the wire, what occurs? What will be the difference between the knob and the other end of the poker?
5. The copper wire connecting the knife and fork in question 6 of generation of current is turned so as to be in the magnetic meridian, the silver being to the south and the steel to the north. A small magnetic needle is placed underneath the wire, will the wire exert any action upon the needle? If so, what action?
6. After the current has been generated, if asked to give some visible proof of its existence, how will you do it?
7. If a strong voltaic current is sent in succession through a thin

platinum wire, through acidulated water, and then through a wire which surrounds a common poker, what is the effect produced in each case?

8. How is it that iron filings sprinkled over a copper wire along which an electric current is passing stick to the wire?
9. Describe some experiment to prove that, when the terminals of a voltaic battery are connected by a wire, the battery itself is traversed by an electric current.
10. A piece of copper wire is wrapped spirally round a ruler from end to end, and the ruler is hung horizontally, so that it can turn about its centre while a current is passing through the wire. How can you tell, by using a bar magnet, in which direction the current is passing?

#### **Galvanometer.**

1. Describe and explain the ordinary multiplying galvanometer.
2. A steel knife and a steel fork are connected by wires with a galvanometer. The knife and fork are used to cut a juicy and well-salted beefsteak, what will be the effect upon the galvanometer? What will be the effect when a silver fork is substituted for the steel one, the steel knife being retained?
3. A current passing through a long wire is so weak that, when the wire is stretched over and parallel to a suspended magnetic needle, the needle is not perceptibly deflected. Describe, and explain an arrangement which would enable you to obtain a movement of the needle by the action of the current.

#### **Grove's Battery.**

1. What is the part played by nitric acid in Grove's battery?
2. Give a sketch of Grove's battery, and state the uses of its various parts.
3. The current from a Grove's battery is sent through two pieces of wire, one of silver, the other platinum, of the same length and thickness. The silver remains cool, the platinum is heated to redness, why?
4. Amalgamated zinc plates are employed in Grove's voltaic battery. How are the plates amalgamated, and what useful purposes does amalgamation serve?
5. Describe one (but only one) of the three following forms of voltaic cells: Daniell's, Grove's, Bunsen's, stating what changes go on in it while the current is passing.

**Electric Telegraph.**

1. State what you know about the electric telegraph.
2. A current flows through a telegraph wire between Edinburgh and London, but we do not know whether it comes from Edinburgh or from London. Supposing this knowledge desired, how would you obtain it?
3. A current passes in a telegraph wire from south to north; you bring a magnetic needle suspended horizontally under the wire, what effect will be observed?
4. You are required to prove that a current of electricity is passing through a telegraph wire to which you have access. How would you do it?
5. How are wires carrying a voltaic current usually insulated? What is the meaning of insulation?

**Electrolysis.**

1. A voltaic current is sent through water, the water is decomposed, and two gases are formed; what are they, and where do they make their appearance?
2. Tell me what you understand by chemical combination and chemical decomposition, illustrating your answers by reference to the formation and decomposition of water.
3. Give me a good example of chemical combination, and chemical decomposition, brought about by one and the same voltaic current.
4. State what you know regarding the substances oxygen and hydrogen. How would you mix them, and deal with them, so as to form water? How would you reduce that water again to oxygen and hydrogen by a voltaic current?
5. You are required to sketch and describe an apparatus in which water may be decomposed by voltaic electricity; to name the bodies produced by the decomposition, and to briefly describe their properties.
6. State what you know about the process of electroplating.
7. A vessel containing a solution of salt coloured with a little litmus or indigo is divided into two parts by a partition formed by stitching together several layers of blotting-paper. Two wires, coming from the two ends of a Grove's battery, are dipped into the liquid on opposite sides of this partition. On one side the colour is observed to disappear. Explain its disappearance, and mention

- the end of the battery (whether the zinc or the platinum end) from which the wire which destroys the colour proceeds.
8. A piece of platinum is to be coated with copper by the help of a voltaic battery. Describe some arrangement that might be employed for this purpose.
  9. How would you arrange an experiment for the decomposition of water by an electric current? Give a sketch of the arrangement, and show where the different components of the water would be separated.

### General.

1. I wish you to state fully the meanings of the two terms "Frictional Electricity" and "Voltaic Electricity," and why they are employed.

### Induced Currents.

1. You have a metal hoop. Describe (and give a figure of) some arrangement by which, without touching the hoop, you could make electric currents pass round it, first one way and then the other.
2. One pole of a strong bar magnet is put through a copper ring and quickly taken out again. This is done repeatedly and quickly. Although the magnet and ring are not allowed to rub against each other the ring becomes slightly heated; why is this?
3. Describe any one method by means of which an induced current in a wire may be kept up for some time.

### Polarization.

1. Two copper wires connected, one with the zinc end and the other with the platinum end of a voltaic battery, but not connected with each other, are brought near a piece of sealing-wax that has been rubbed with flannel and then nicely balanced on a point. Would the wires differ in any way in their action on the sealing-wax? If so, how? and why?
2. Two large insulated flat brass plates are set facing each other and very near together. A wire from one of them is joined to the zinc end of a battery of a great many cells; and a wire from the other plate is joined to the other end (copper or platinum) of the battery. Without touching either the wires or plates with conductors, the wires are removed from the plates, and the plates then moved to a distance from each other. What will now be the electrical condition of each plate?



# INDEX.

	PAGE
Action of Points . . . . .	31
Artificial Magnets . . . . .	1
Astatic Galvanometer . . . . .	48
Atmospheric Electricity . . . . .	40
Attraction of Soft Iron . . . . .	5
Attraction, Electrical . . . . .	15
Attraction of Currents . . . . .	52
Chemical Effects of Current . . . . .	52
Coercive Force . . . . .	4
Condensation . . . . .	33
Condenser . . . . .	34
Conduction . . . . .	19
Declination . . . . .	12
Dipping Needle . . . . .	12
Directive Force of Earth's Magnetism . . . . .	10
Discharge, Electrical . . . . .	39
Distribution of Electricity . . . . .	29
Distribution of Magnetism . . . . .	3
Electrical Machine . . . . .	32
Electric Fluids, Theory of . . . . .	23
Electric Spark . . . . .	37
Electric Currents, Theory of . . . . .	45
Electrolysis . . . . .	55
Electromotive Force . . . . .	54
Electrophorus . . . . .	28
Electroplating . . . . .	57
Electroscope . . . . .	19
Examination Questions . . . . .	64
Floating Battery . . . . .	51
Heat and Electricity . . . . .	40
Heat and Magnetism . . . . .	8

	PAGE
Heating Effects of Current . . . . .	60
Horizontal Intensity . . . . .	13
Inclination . . . . .	12
Induced Currents . . . . .	61
Induction, Electrical . . . . .	22
Induction, Magnetic . . . . .	6
Isolation . . . . .	19
Leyden Jar . . . . .	35
Light Bodies, why attracted . . . . .	25
Loadstone . . . . .	1
Local Analysis . . . . .	26
Magnetic Curves . . . . .	8, 9
Magnetic Effects of Current . . . . .	46
Magnetic Equator . . . . .	2
Magnetic Fluids, Theory of . . . . .	6
Magnetism, Definition of . . . . .	1
Magnetism of Earth . . . . .	9-13
Magnetizing Effects of Electric Discharge . . . . .	44
Meridian, Geographical . . . . .	12
Meridian, Magnetic . . . . .	12
Needle Telegraph . . . . .	49
Percussion, Effect of . . . . .	10
Permanent Magnets . . . . .	1
Polarity . . . . .	2
Polarity, to reverse . . . . .	7
Polarization . . . . .	57
Repulsion, Electrical . . . . .	15
Return Shock . . . . .	42
Syllabus . . . . .	63
Temporary Magnets . . . . .	2
Thunder and Lightning . . . . .	40
Total Force . . . . .	13
Vertical Intensity . . . . .	13
Voltaic Electricity . . . . .	45
Voltameter . . . . .	54

